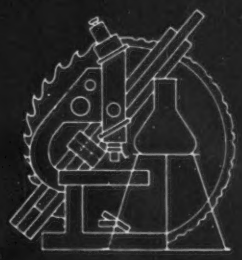
HOW TO SET UP A SMALL SAWMILL—p. 209

Forest Products Journal



Vol. VI, No. 6 June, 1956

—Photo courtesy Edward Hines Lumber Co.

Self-Service Lumber Displays Are Silent Salesmen Reaching Huge Do-It-Yourself Market—p. 17–A

Published by the FOREST PRODUCTS RESEARCH SOCIETY BOX 2010 MADISON 5, WISCONSIN

. . . for increased assembly time of glue-spread veneers

. . . for improved durability

UPGRADE YOUR UREA-FORMALDEHYDE ADHESIVES WITH CYMEL* RESIN 401

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FOR EXAMPLE: Here's what happens as you increase the amount of CYMEL 401 in standard URAC® 180 or 186 glue formulas:

% CYMEL 401 (of Resin Solids)	Maximum Assembly Time (Hours)		Durability (Boil Resistance — Hours Without Delamination)	
	Unextended Formulation	Intermediate Flour-Extended Formulation	Unextended Formulation	Flour-Extended Formulation
0	less than 3	less than 3	less than ½	less than ½
5	12 — 15	10 — 12	1	1
10	15 — 20	20 — 24	2	2
15	20 — 24		3	
20	20 — 24		4	

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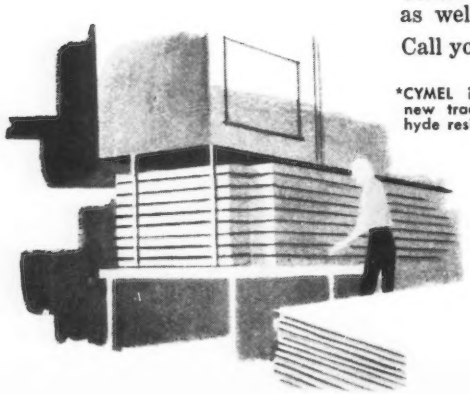

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THE FOREST PRODUCTS JOURNAL is published monthly by the Forest Products Research Society, P. O. Box 2010, University Station, Madison 5, Wisconsin. Entered as Second-Class Matter, April 1952 at the Post Office, at Madison, Wisconsin.

Annual subscription rate, $15.00; single copies $1.00, except October Yearbook Number, $4.00. Annual subscription rate is $11.25 with voting, associate, and supporting memberships in the Society. Remittances should be made payable to the Forest Products Research Society.

Correspondence on editorial matters should be addressed to the Editor, at the Executive Office. The Society is not responsible for views expressed in publications.

FOREST PRODUCTS JOURNAL

Vol. VI, No. 6 June, 1956

CONTENTS

Page

FPRS News-Digest ---- 9–A, 32–A

MARKETING

Merchandising Forest Products ---- J. R. Welch 17–A

SAWMILLING

Handbook for Small Sawmill Operators—Part III. Mill Setup ---- K. C. Compton and G. E. Bell 209

A Review of Sawmill Developments in the Northeast ---- S. W. Tolle 19–A

GLUES AND GLUING

Gluing Developments Related to the Navy's Shipbuilding Program ---- W. H. Miles and J. G. Kuenzel 213

Strength and Elastic Properties of Two-Species Laminated Wood Beams ---- R. N. Jorgensen 215

VENEER AND PLYWOOD

Preliminary Report on a Proposed New Method of Estimating the Service Life of Exterior Grade Plywood ---- W. J. Pearson 221

SEASONING

Sorption Hysteresis in Relation to Wood Thickness ---- A. P. Schniewind 225

PRESERVATION

Variation in Taxifolin Content of a Douglas-Fir Stem Exhibiting Target Ring ---- R. W. Kennedy and J. W. Wilson 230

STRENGTH PROPERTIES

Progress Report on Survey of Bending Strength Values of Dimension Lumber Used in Farm Work Buildings in the Northeastern States ---- M. D. Ostrander 232

PAINTS

Swelling of Paint Films in Water: VII. Latex Vehicles ---- F. L. Browne 235

MACHINING

Planer Feeding Difficulties ---- J. E. Hyler 240

EDUCATION AND RESEARCH

Forest Products Research ---- H. E. Dadswell 21–A

Operational Research in the Wood Turning Industry ---- J. W. Tebbets 24–A

PACKAGING

Consumer's Point of View on Fruit and Vegetable Shipping Containers ---- C. B. Moore 26–A

DEPARTMENTS

Meet FPRS 100 Company Supporting Members ---- 28–A

Around the World in Forest Products Research ---- 29–A

Abstracts from Current World Literature ---- 30–A

Review of FPRS Section Meeting Papers ---- 31–A

FPRS Employment Service ---- 34–A

Index to Advertisers ---- 36–A

IMPORTANT FPRS DATES

Sept. 24, 1956: Joint Meeting of Inland Empire and Pacific Northwest Sections, Lewiston, Idaho

Oct. 1956: Midwest Section Meeting, Rockford, Ill.

Oct. 1956: Upper Mississippi Valley Section Meeting, Wausau, Wisconsin

Fall 1956: Carolinas–Chesapeake Section Annual Meeting, Pinehurst, N. C.

Fall 1956: Mid-South Section Annual Meeting, Laurel, Miss.

Dec. 7–8: Florida–Georgia–Alabama Section Annual Meeting, Athens, Ga.

March 1957: Eastern Canadian Section Annual Meeting, Montreal, Quebec

June 24–28, 1957: Eleventh National Meeting, Buffalo, N. Y.

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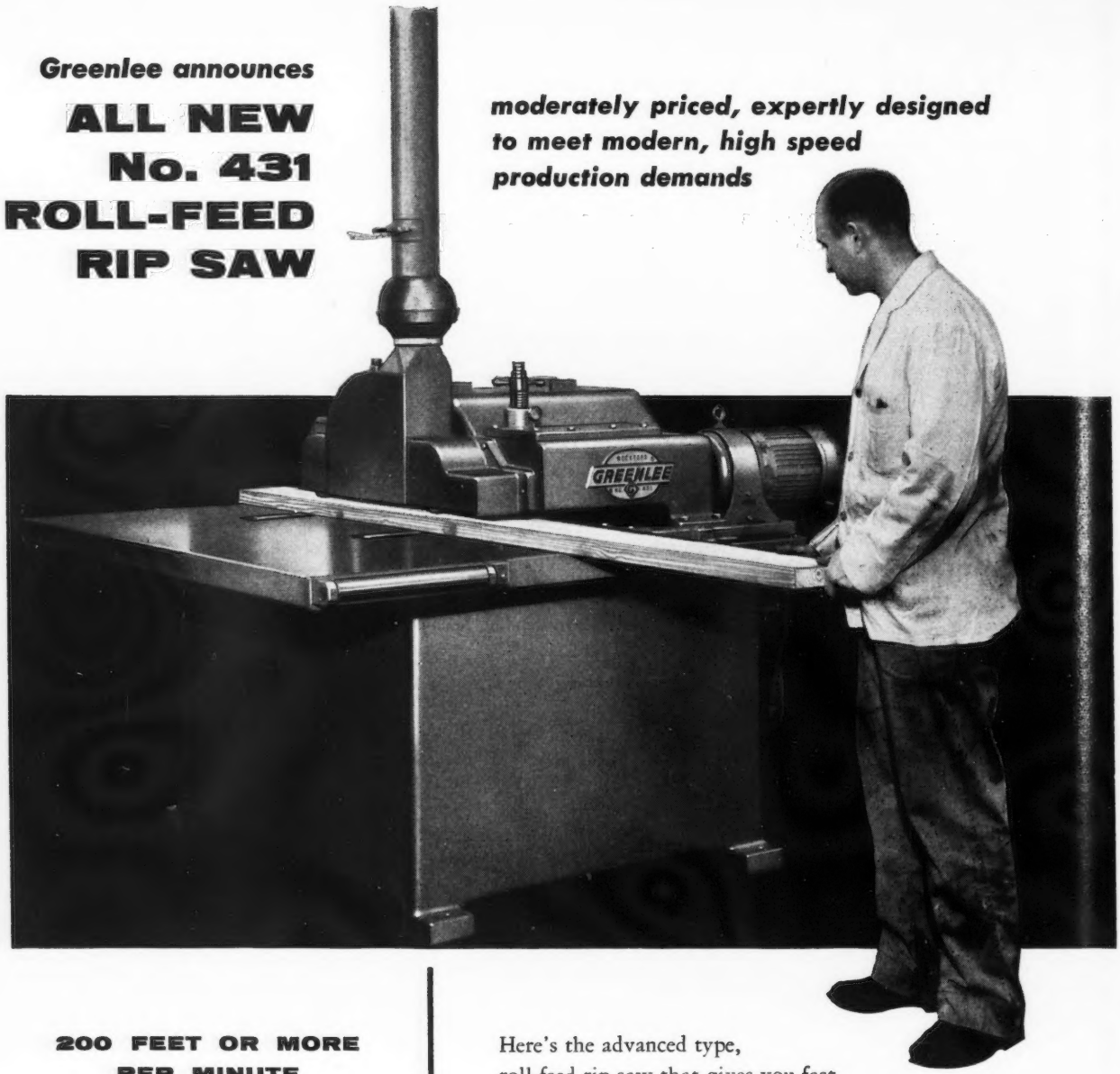

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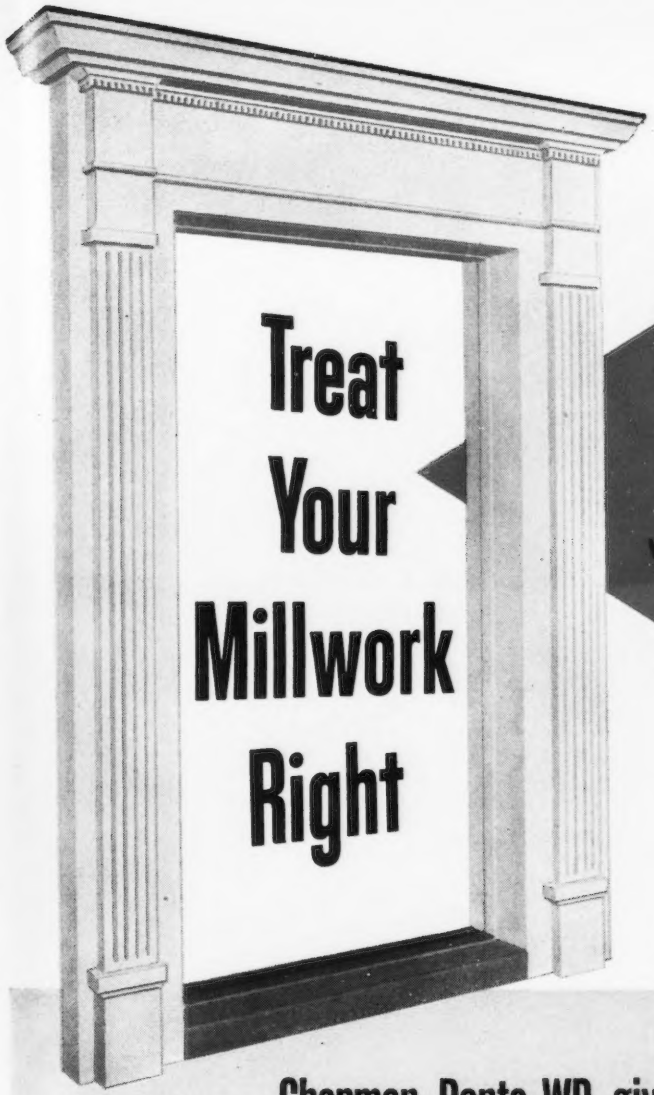

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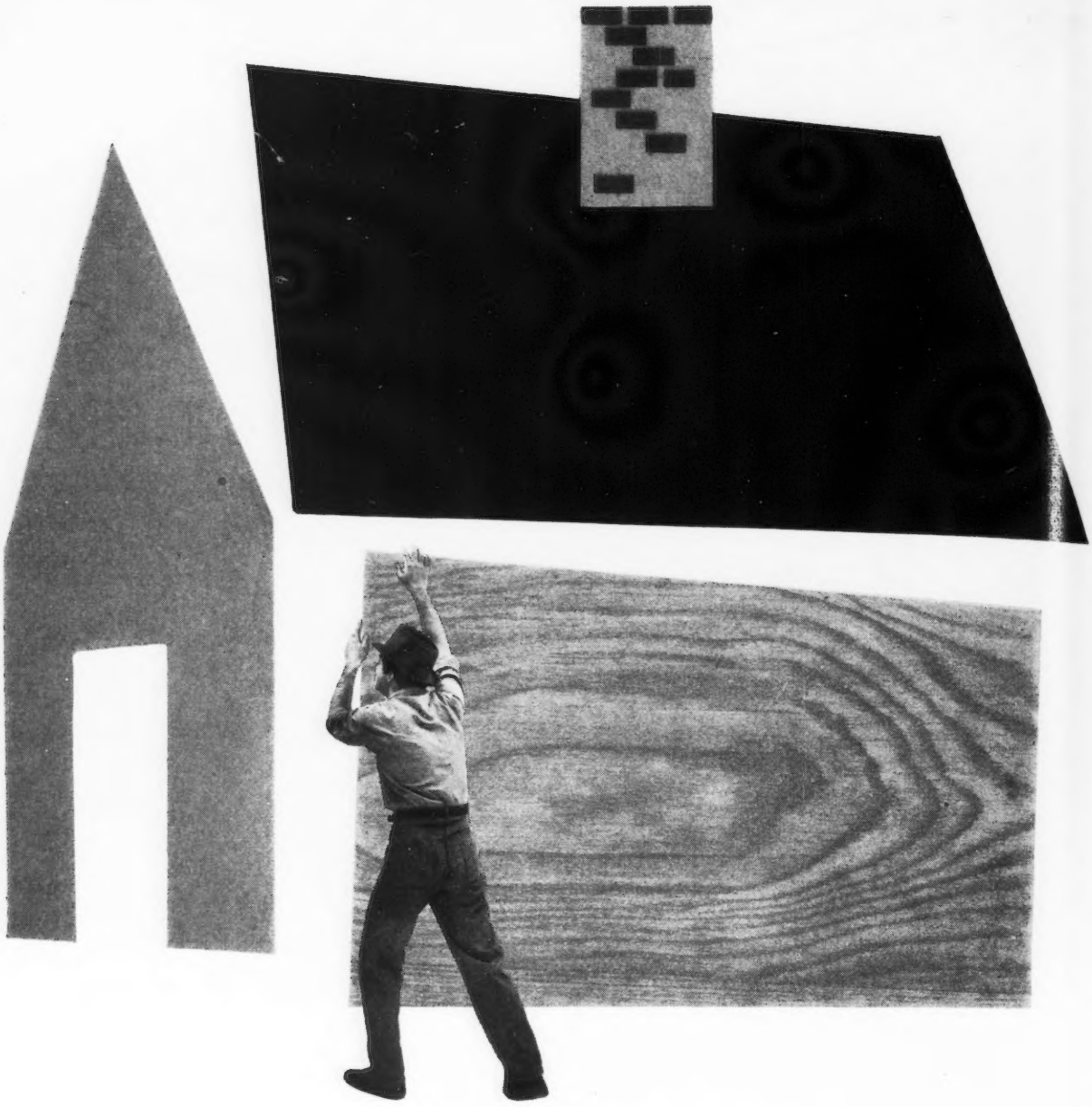

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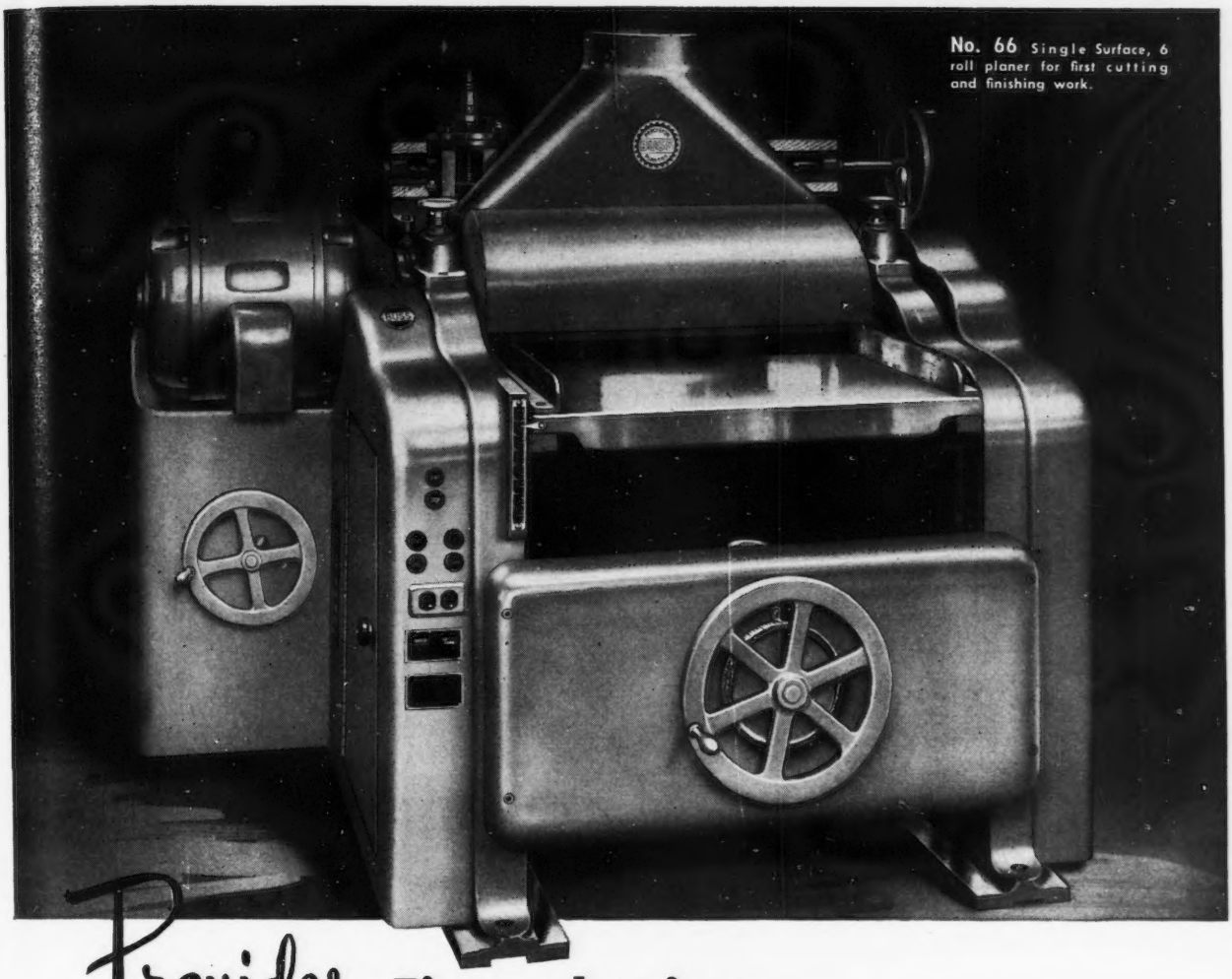

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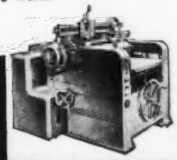
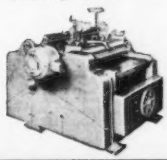
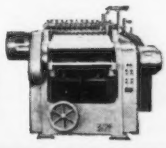


No. 44 Single Surface, 4 roll planer for first cutting and finishing work.

No. 88 Double Surface, 8 roll planer for first cutting and finishing work.



No. 55 Heavy duty Double Surfacer for planing rough lumber.



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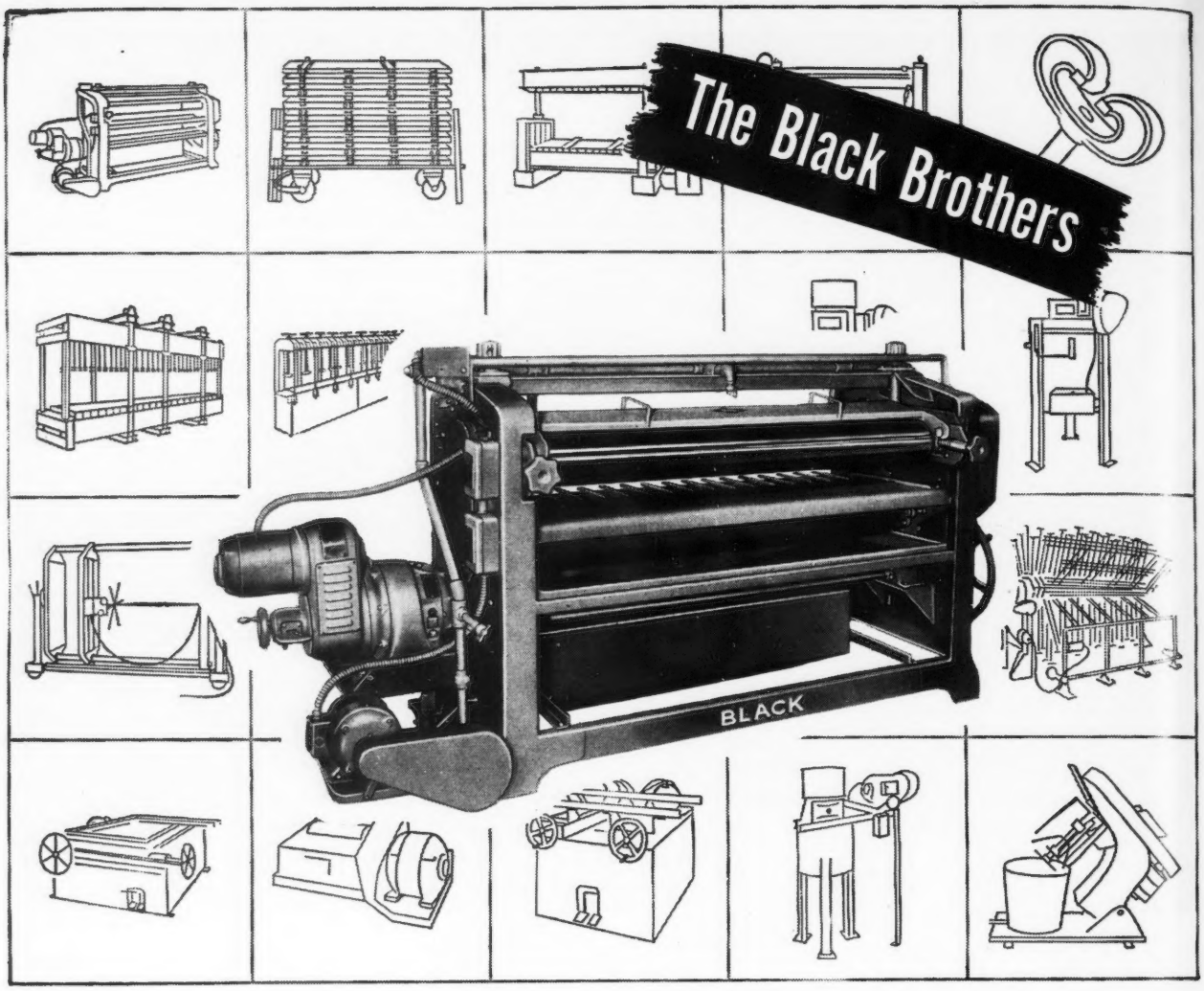

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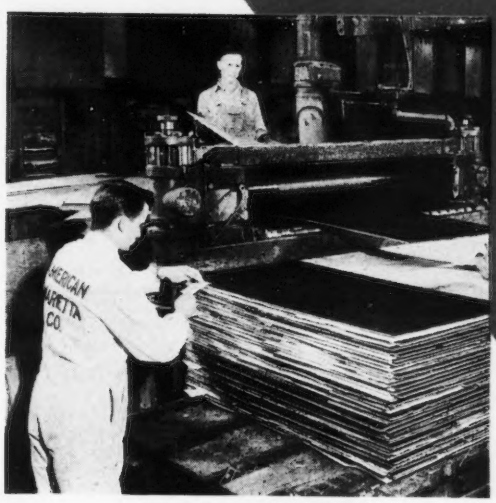
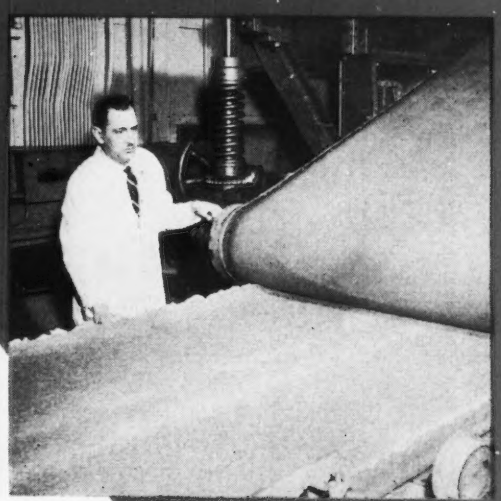


IN PLYWOOD



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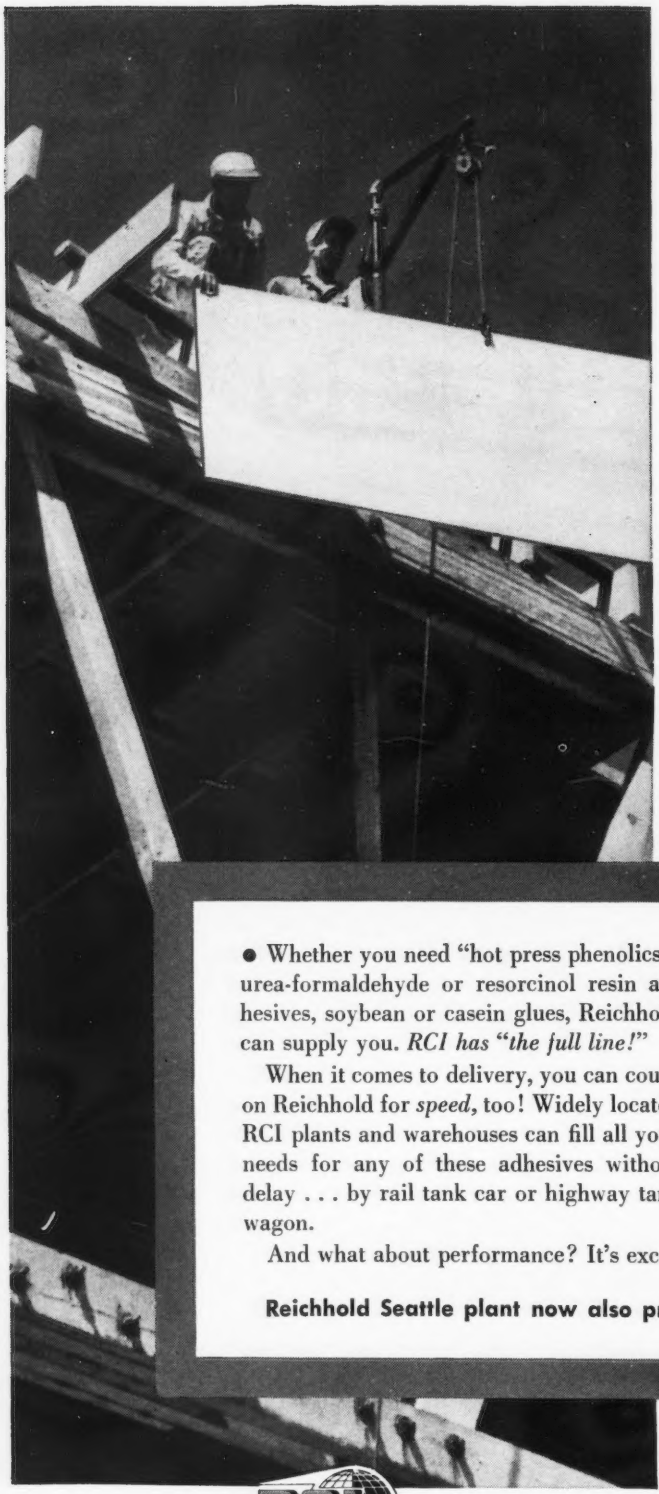
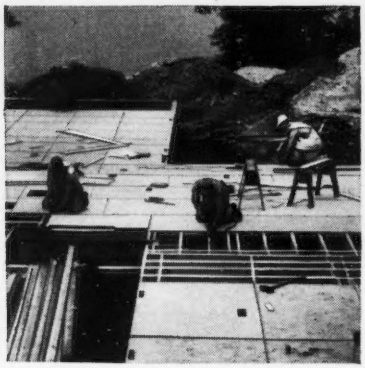


Roof or subfloor — You can expect uniform results in bonding structural plywood of all grades, when you use high quality RCI adhesives . . . tailored to specific needs.



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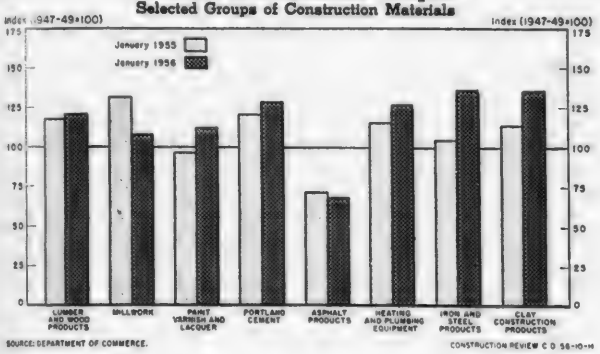
FPRS NEWS-DIGEST

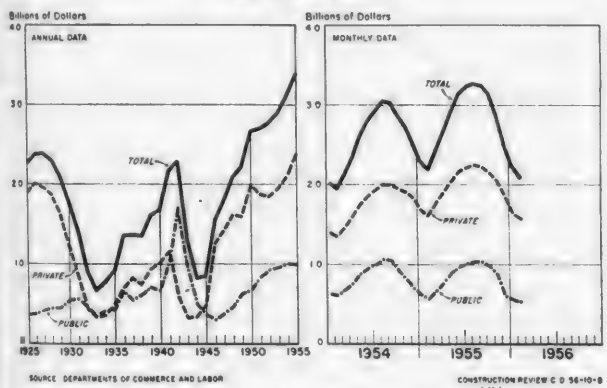
Volume VI JUNE, 1956 Number 6

GRAPHIC TRENDS

Indexes of Materials Output
Selected Groups of Construction Materials



New Construction Put in Place
(In 1947-49 Prices)



UTILIZING RESIDUES—Survey of markets for wood residues in Southeast shows strong demand for chips by pulp mills, raw material for chipcore, and shavings for use as litter by poultry farmers. More than 10 board plants are operating or under construction in Southeast, compared to two a year ago.

—Southeastern Forest Experiment Station

LUMBER PRODUCTION—Hardwood lumber and flooring production was up 3.3% in first quarter of '56 over same period in '55. Total production was off 2.3%, to 8.931 billion board feet.

NLMA

BUSINESS OUTLOOK

NEW HARDWOOD MARKETS—$3 million expansion program including construction of additional plant capacity to use neutral sulphite semi-chemical process of making pulp and container board from hardwoods has been announced by Huss Ontonagon Pulp and Paper Co., Chicago. New firm recently purchased National Container Corp. pulp and paper mill at Ontonagon, Mich., plus more than 30,000 acres of tree farms.

WOOD VS. COMPETITION—Economy and efficiency of wood and timber in construction is exemplified by $245,538 saving in low bid calling for use of 6,400 pressure treated timber piles for permanent foundations for new buildings at New York's Idlewild airport. The bid won out over concrete-filled steel piles.

—Timber Digest

BARK EXTRACTING INDUSTRY—The Kurth bark extraction process which will provide basis for new industry in Pacific Northwest will shortly be available for licensing. Developed by Dr. E. F. Kurth at Oregon Forest Products Lab., process is designed to extract waxes, tannins, and fine chemicals from barks of native timber trees. Oregon lab solicits inquiries from firms interested in possible licensing.

RESEARCH—About $5 billion is being spent on research in U. S. this year, including $3 billion in industrial labs. Union Carbide & Carbon Corp.'s David Swan says $5 to $20 billion will be invested as capital to take advantage of each $1 billion expended in industrial research.

—Industrial Research Newsletter

SOCIETY NEWS

Saunders Elected Chairman of FPRS Northeast Section

Donald K. Saunders, President, Saunders Bros., Westbrook, Maine, was elected Chairman of the Northeast Section at the annual meeting April 19–20 in Springfield, Mass. Named Vice-Chairman was Eric A. Anderson, State U. College of Forestry, Syracuse, N. Y., and re-elected Secretary-Treasurer was William J. Delmhorst, Delmhorst Instrument Co., Boonton, N. J.

More than 120 persons attended the meeting, which featured three technical sessions on "Synthetic Wood Materials." Idea exchange sessions were held on merchandising and marketing, research in wood products, machining, and education and employment. The meeting concluded with optional plant tours to Milton Bradley Co., Savage Arms Corp., A. G. Spalding & Bros., and Wackerbarth Box Shop.

Charles R. Lockard, retiring Section Chairman, was toastmaster at the annual banquet. He presented the Northeast Student Award of $150 to Thomas W. Smeal, Pennsylvania State University. Principal speaker was O. P. Cohen, Monsanto Chemical Co., who discussed "The Exterior Durability of Melamine Resin Adhesives."

At the business meeting, it was announced that changes in Section By-Laws had been adopted by mail ballot. Mr. Lockard presided at the meeting and introduced new officers present. Frank T. Parrish, Northeast Regional Executive Board Member, described plans for the 1957 National Meeting to be held in Buffalo, N. Y.

Preprints of papers presented at the meeting are available at $2 per set from Richard F. West, Dept. of Forestry, Rutgers University, New Brunswick, N. J. Included are papers on epoxy resin bonding, charcoal, the ideal glue, wood particle molding, chipcore manufacture, economics of the particle board industry, gluing and fabricating flush doors, flexible paper and fabric-backed veneers, and strength properties of plywood.

Officers Elected at Northern California Section Meeting

Homer N. Stephenson, Sacramento Box and Lumber Co., was elected Chairman of the Northern California Section at the annual meeting April 27 in San Francisco. Other new officers are: N. T. Shelton, Diamond Match Co., Vice-Chairman; R. M. Kuhn, Rees Blow Pipe Co., Secretary-Treasurer; and Fred E. Dickinson, California Forest Products Lab, Trustee.

Four papers were presented at an afternoon technical session on chemical utilization, waste utilization, grading veneers, and re-logging mixed conifers. Retiring Chairman E. P. Ivory presided at the evening dinner meeting, addressed by Dean Henry J. Vaux of the California School of Forestry.

Roos Elected Chairman of Eastern Canadian Section

K. O. ROOS

Kenneth O. Roos, General Manager, Booth Lumber Ltd., Tee Lake, Quebec, was elected Chairman of the Eastern Canadian Section at the annual meeting in Toronto March 1 and 2. Other new officers are: E. A. Thompson, Canada Creosoting Co., 1st Vice-Chairman; R. F. DeGrace, Executive Vice-President, Canadian Institute of Timber Construction, Secretary; and P. M. Morley, Canadian International Paper Co., Treasurer. Morley served as Section Chairman during 1955.

Members toured the newly opened Canadian Institute of Home Construction in Toronto to view new materials and developments. The organization is similar to the U. S. National Institute of Home Builders.

Modular Construction Theme of Midwest Section Meeting

"The Modular System of Home Construction" was the principal subject of the spring meeting of the Midwest Section May 2 and 3 in Dubuque, Iowa. Section Chairman L. J. Fitzpatrick, President, J. J. Fitzpatrick Lumber Co., Madison, Wis., presided at the technical sessions.

Official luncheon speaker was William Demarest, Assistant Director, Construction Dept. and Research Institute, National Assoc. of Home Builders, Washington, D. C. Demarest has served as modular coordinator of the American Institute of Architects. It was pointed out that modular construction is the simplification of building dimensions by utilizing a 4-inch unit of measurement. Its purposes are to reduce building costs by: saving labor through prevention of construction errors and saving material by using standard size building material.

Other speakers on modular construction were Wayne Norman, Carr, Adams & Collier Co.; J. E. Kinnebrew, Kroehler Mfg. Co.; and F. E. O'Dowd, Edward Hines Lumber Co. Treated millwork was discussed by A. Klemm, Monsanto Chemcial Co.

Interest in humidification apparatus is high, it was demonstrated by floor discussion following a talk on "Why We Humidify" by Leo Iglewski, President, Igloo Cabinet Co., Chicago. O. K. Hutchison, Central States Forest Experiment Station, reported on economics of present and future timber resources in the Midwest.

Lamination in Construction Discussed at Minneapolis Meeting

Robert Eby, Chief Engineer, Rilco Laminated Products, Inc., was main speaker at a dinner meeting of the Upper Mississippi Valley Section held May 3 at Hotel Francis Drake, Minneapolis. He discussed latest aspects of laminated timbers from the standpoint of their manufacture and use in construction.

F–G–A Section Vice-Chairman, Membership Committee Named

Rufus H. Page, Georgia Forestry Center, Macon, has been named Vice-Chairman of the Florida–Georgia–Alabama Section. He succeeds E. M. Conway, recently transferred to Colorado by the U. S. Forest Service. Page will also serve as program chairman for the Section's annual meeting Dec. 7 and 8 in Athens, Ga.

Appointment of Ralph Peter, Athens–Macon Research Center, U. of Georgia, as Section Membership Chairman, has also been announced by Chairman J. B. Huffman. Assisting as state membership chairmen are: W. B. Black, Alabama; B. Turner, Georgia; and Amos Kelly, Florida.

Oregon and Washington Students Given FPRS Memberships

Five students at Oregon State College and the U. of Washington College of Forestry have been awarded memberships in FPRS by the Pacific Northwest Section. Memberships previously given to five students at the U. of British Columbia were announced earlier.

The Oregon students are: M. B. Carpenter, J. P. Carstensen, G. A. Ellestad, R. L. Krahmer, and J. S. Mothershead. Students at Washington receiving the memberships are: D. P. Abrahamson, D. E. Baker, J. F. Behrens, J. A. Haase, and L. M. Steffensen.

Carolinas–Chesapeake Section Announces New Officers

John Colucci, Jr., Southern Box and Lumber Co., was elected Chairman at the recent annual meeting of the Carolinas-Chesapeake Section. Other officers are: J. B. Veach, Jr., Bemis Hardwood Lumber Co., Vice-Chairman; J. S. Bethel, N. C. State College, Secretary-Treasurer; and R. C. Buchholz, W. L. Irwin, and P. Rambaugh, Trustees.

Pictorial Highlights of Three FPRS Section Meetings

Discussing Eastern Canadian Section growth during recent meeting are FPRS Executive Secretary F. J. Rovsek, Section Secretary Bob DeGrace, and FPRS President Moss B. Christian.

Contributing to success of Eastern Canadian meeting were: Prof. Art Michell, U. of Toronto; Louis Roy, Reichhold Chemicals, Ltd., and Peter Morley, past Chairman and newly elected Treasurer.

Portion of Eastern Canadian members who toured Canadian Institute of Home Construction.

Participants in opening session of Northeast Section Meeting at Springfield, Mass. April 19–20 were: W. T. Nearn, J. T. Clarke, Frank Parrish (presiding), D. Brouse, and A. L. Midyette.

Particle board manufacture, testing, and economics were discussed by panel during Northeast meeting. Speakers were, seated: W. C. Lewis, A. M. Fisken, H. C. L. Miller; standing: J. A. Hauter (presiding), R. R. Blumenstein, and J. M. Crafton.

National Membership Chairman Frank Parrish places pin at Baldwinsville, Mass. in Northeast membership map after signing up M. J. Wesolowski, Temple Stuart Co., Baldwinsville furniture firm.

Luncheon speaker at Midwest Section meeting in Dubuque, Iowa, was W. Demarest, National Assoc. of Home Builders. At left is Section Chairman L. J. Fitzpatrick, right is Harvey Gill, Carr Adams & Collier Co.

Leo Iglewski discusses "Why We Humidify" as program chairman Dwight Bensend, Iowa State College, and O. K. Hutchison, Central States Forest Experiment Station, look on.

Additional speakers and FPRS officials attending Dubuque meeting were: R. L. Hiller, North–Central Regional Board Member; Wayne Norman; J. E. Kinnebrew; L. J. Fitzpatrick; Masonite Corp. Development Department specialist substituting for J. J. Allegretti. and F. E. O'Dowd.

Portion of group of more than 75 persons attending Midwest Section meeting in Dubuque.

F–G–A Section Committees Aid Program Planning

Nine subject matter committees have been appointed by J. B. Huffman, Chairman, Florida–Georgia–Alabama Section, to assist in planning future Section Meeting programs. The committees will recommend possible discussion topics and suggest meeting speakers. The action was taken, Huffman said, to give all groups a voice in Section activities.

Appointments were made to the following committees: chemical utilization, seasoning and moisture relations, gluing and glued products, utilization of wood wastes, wood use in construction, wood preservation, marketing, logging and milling, and wood containers. Other committees may be named on request of Section members.

Contribute to Building Fund

The Midwest Section recently gave $500 to the FPRS Executive Office Building Fund, in addition to $1000 previously contributed. The Ohio Valley Section has voted a $100 donation to the building fund.

INDUSTRY NEWS

Kentucky Firm Plans Residue Utilization Plant

Sawmill residues and low-grade hardwoods will be the chief raw materials for a new $2.4 million plant planned near Burnside, Ky., by Cumberland Corp., newly organized Kentucky firm. Hardwood charcoal briquets will be the firm's initial product, with furfural to be made as a by-product.

Upson Company Building New Research Center

Construction has started on a new research center at The Upson Co., Lockport, N. Y. Executive Vice-President James J. Upson announced the modern structure with new research equipment will be completed in July.

The center will be used for improving the firm's present building products and for developing, testing, and evaluating new ones, Mr. Upson said.

New type floor permits quick and simple substitution of nominal 8-inch boards, for the edge-glued boards, in emergency field repairs.

It also will be utilized in exploring new fields of activity and developing such new products as dimensional stabilizers, resins, coatings, adhesives, vapor barriers, waterproofing compounds, and other chemicals by The Upson Chemical Corp., subsidiary firm.

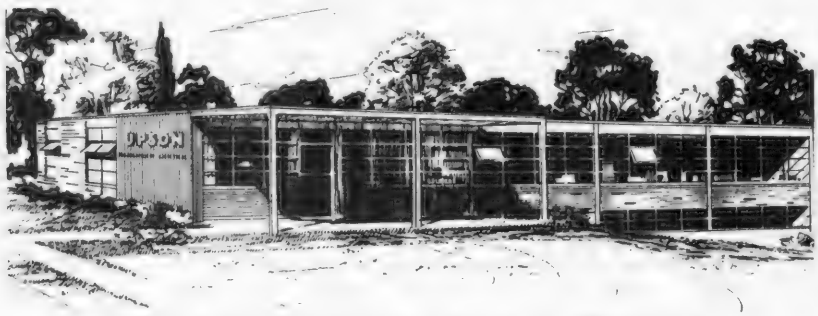
NAFM Reports Big Demand for Space at '56 Fair

Continued high furniture shipments coupled with strong retail demand is increasing interest in NAFM's 1956 Supply, Equipment & Fabric Fair. Both furniture manufacturers and the producers of machinery, equipment, raw materials, and supplies are planning bigger participation in this year's event than last year when 1700 furniture executives attended the showings of 120 exhibitors, according to John M. Snow, NAFM Executive Vice-President.

This year's fair will be held at the Conrad Hilton Hotel, Chicago, August 26–30, in conjunction with the 28th Annual Convention of the National Assoc. of Furniture Manufacturers.

New Veneer Plant

A new green veneer plant of Evans Products Co. is nearing completion at Gold Beach, Ore. Veneer produced at Gold Beach will be shipped to Evans' Coos Bay, Oregon, plant for processing. In addition to the new plant and the Coos Bay operation, the firm has plants at Roseburg, Ore., Vancouver, B.C., and Plymouth, Mich.



Ground was broken in March for new research center at The Upson Co.

Army Testing Lighter All-Wood Truck Body

The U. S. Army is now road-testing the fourth prototype of an all-wood military truck body, developed at the laboratory of Timber Engineering Co. Redesigning has reduced the truck body's weight to 1,180 pounds, about 500 pounds lighter than the Army's steel truck body of similar capacity.

A major change in floor design has reduced overall weight, increased durability, and simplified repairs. The new floor consists of individual 8-inch edge-glued black gum boards running full length of the floor. The narrower floor boards minimize warping and permit the use of sound cuttings from low-grade lumber.

NAMES IN THE NEWS

A. G. Battaglia has been named head of a newly organized Structural Adhesives Dept. at National Adhesives, New York City. The new department will specialize in new types of adhesive and bonding techniques for use in woodworking, construction, aircraft, structural, and electronic

A. G. BATTAGLIA

J. COUFAL

P. H. McCORMACK

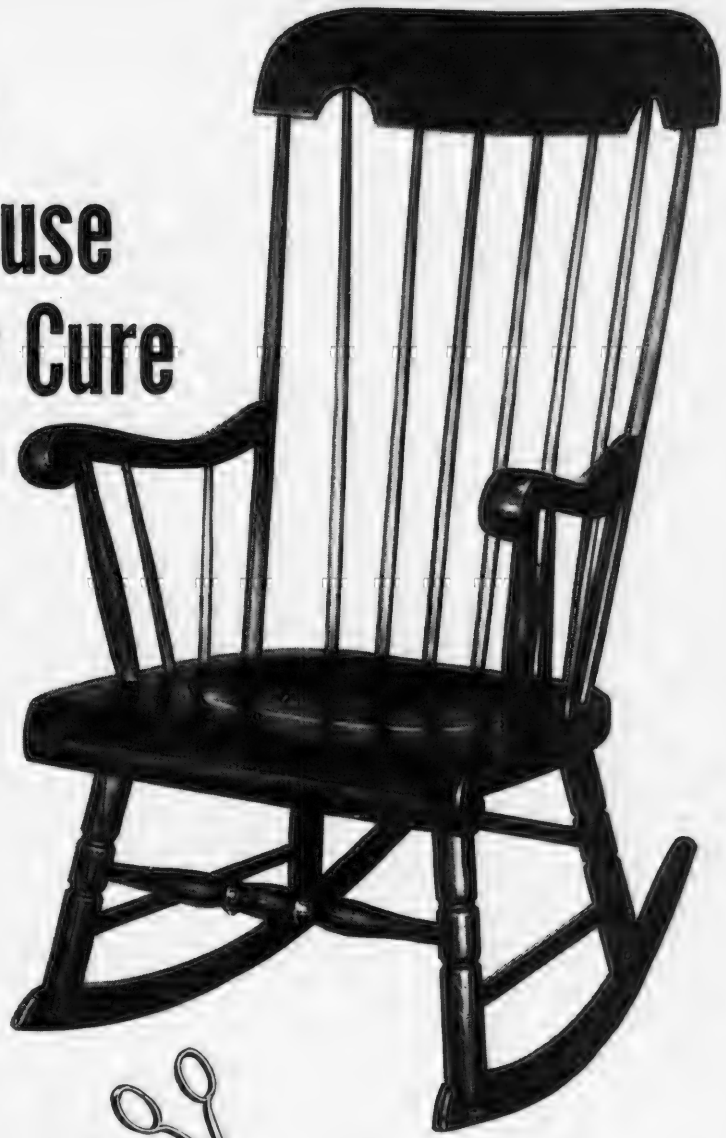
J. SIROTA

fields. **Joseph Coufal** has been appointed sales supervisor of the new group, **Paul H. McCormack** will handle field development of the new types of applications and products, and **Jules Sirota** will be in charge of laboratory development and formulating.

Ralph M. Buechler has been named sales manager of the Pulp and Paper Mill Machinery Division of D. J. Murray Manufacturing Co., Wausau, Wis..

A cooperative program of forest utilization research in Georgia is headed by **Rufus H. Page,** forester jointly employed by the Southeastern Forest Experiment Station and the Georgia Forestry Commission.

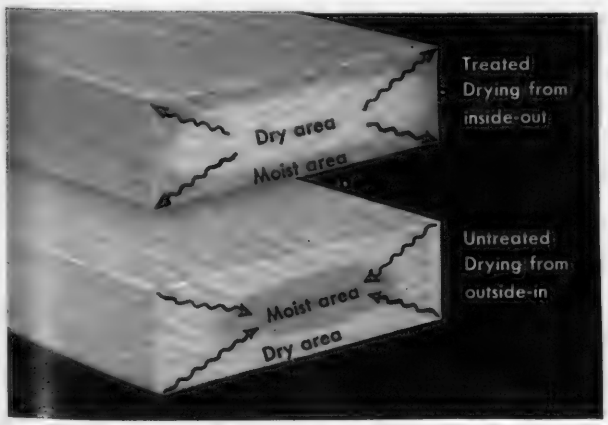
Manufacturers find it pays to use Morton Lumber Cure treated lumber



The Tell City Chair Company, chairmakers since 1865, and makers of the rocker shown at right, started using Morton Lumber Cure treated lumber two seasons ago. The results have been most rewarding. Tell City has found Morton Lumber Cure reduces drying time about one-third, increases cutting yield, and produces check-free lumber.

Hundreds of fabricators now insist on lumber that has been treated with Morton Lumber Cure. They know from experience Morton Lumber Cure increases utilization of rough cut lumber. Lumber also can be dried faster; kiln time and expense can be reduced, with a more rapid turnover of inventory and capital.

What's more, Morton Lumber Cure is compatible with stain-preventing agents . . . will not affect gluability . . . machinability . . . color or finish. Morton Lumber Cure is non-toxic and non-corrosive.



HOW MORTON LUMBER CURE WORKS Morton Lumber Cure reverses the normal drying action. Untreated lumber dries from the outside in. Morton Lumber Cure dries lumber from the *inside out*. This controlled drying greatly reduces checks, honeycomb, warping, and other types of wasteful surface and interior degrade.

SEND FOR MORE INFORMATION TODAY!

Bay Chemical Company

DIVISION

Morton Salt Company

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Please tell me how Morton Lumber Cure can help *me* increase my sales and satisfy customers.

Name_____

Title _____

Company_____

Address_____

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The Perkins Trade Mark is your guarantee of quality and reliability when you purchase glues. Since 1899, customer-confidence in Perkins has grown steadily—a deserved tribute to superior products backed by competent service and rigid ethical standards. When you use a Perkins Glue in your operations, you'll agree with other leading woodworkers—*that Perkins serves you best!*

GLUING PROBLEMS?

Dispose of them by calling upon the skilled assistance of the Perkins Technical Service Department. Specialists in gluing methods will study your particular operations and offer suggestions where pertinent. There is no cost or obligation involved in your use of this unbiased advice.

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For new product beauty,
quality and economy...
44 types, textures
and thicknesses
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Please send me design and production information on Masonite Presdwood® products.
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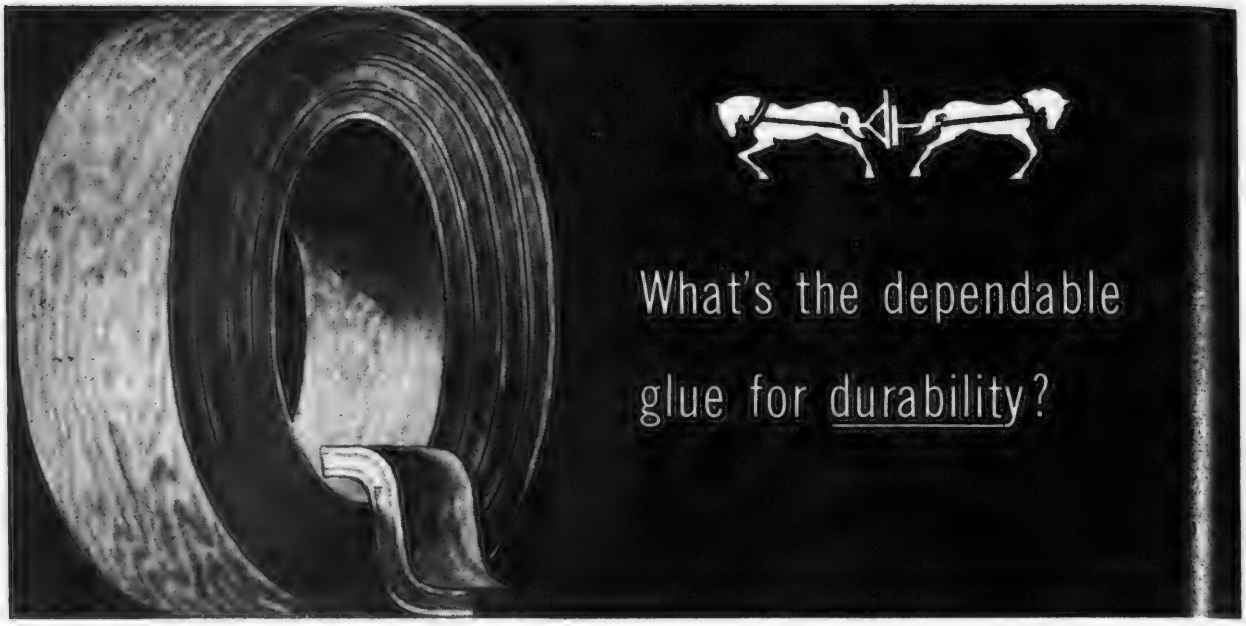
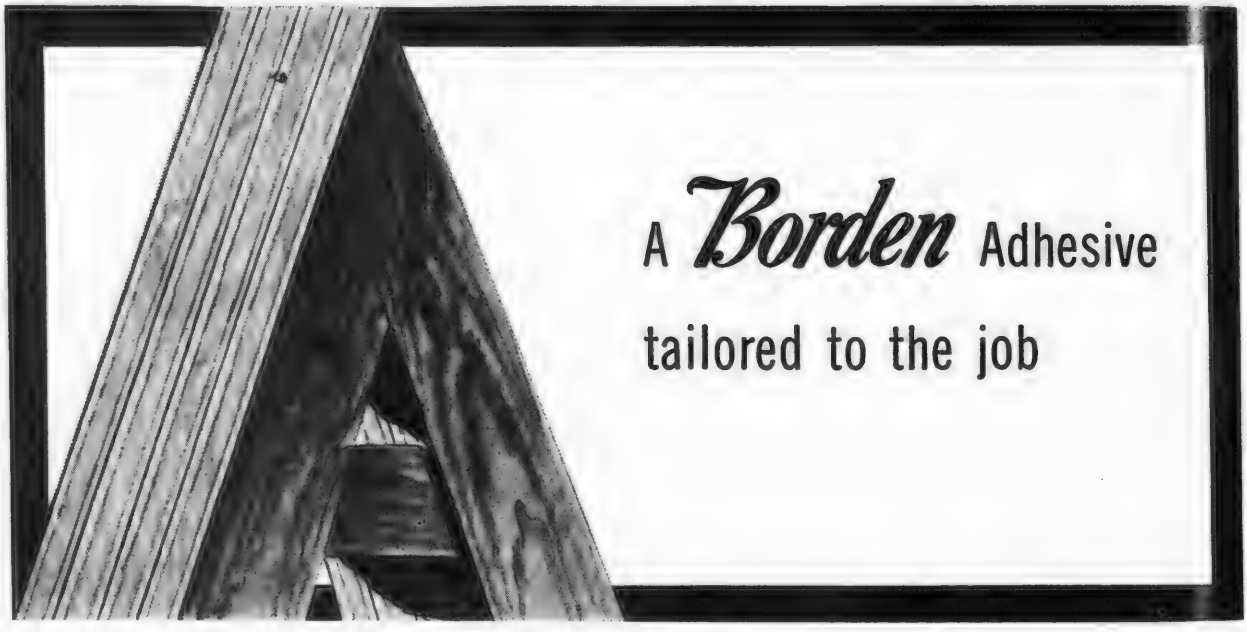
Zone.....County.....





Borden's adhesive specialists have to consider a variety of factors before they can recommend the right glue for each gluing job. Particularly when the *durability* of the glue is an important question.

For example: Will the end product be exposed to heat? Cold? High humidity? Extreme weather conditions? How durable is the product to be? What kind or kinds of woods are to be used? Fir? Gum? Poplar?

These questions and many more are asked by Borden because no one glue or type of glue is durable enough for every job. Therefore, to meet your specifications with the *right* glue, Borden specialists apply 35 years of experience and experimentation with adhesives to your needs. These experts analyze your requirements, and then—by utilizing Borden's wide range of catalysts and modifiers—come up with the best glue for your requirements.

If you would like to receive informative data on this subject of "durability," write for Service Bulletin No. 72a "Durability of Woodworking Adhesives", which sets forth the results of long term durability tests on plywood aged 10-16 years bonded with synthetic resins. The Borden Company, Chemical Division, Dept. FPJ-66, 350 Madison Ave., New York 17, N. Y.

INDUSTRIAL ADHESIVES

THE *Borden* COMPANY

CHEMICAL DIVISION

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FPRS Forest Products Journal

Vol. VI, No. 6
June, 1956

Merchandising Forest Products[1]

JAMES R. WELSH

President, Welsh Plywood Corp., Memphis, Tennessee

A rapidly growing market for wood has been created by the do-it-yourself movement. To reach this market, it is necessary to make it easy for the consumer to buy. This can be done by self-service retail lumber outlets, using display racks and other merchandising aids, adopting easily understood measuring and grading terms, and attractive packaging. An analysis of this new consumer market is suggested, to learn additional ways to reach this market.

MERCHANDISING IS A FIELD which covers the entire American system of selling. Merchandising includes the development of a product, testing that product, advertising it, direct sales of that product to a dealer, and sale of the product to a consumer. Merchandising has to do with all the methods and means connected with moving a product to a consumer. Expressed most simply, merchandising is the process by which the right product, at the right price, is offered to the right customer at the right place, at the right time.

We in the forest products industry are falling down in one particular branch of merchandising, and that has to do with selling our product to the small consumer. There is a great movement going on in America, called the "do-it-yourself" market. This market is growing day by day, and will continue to grow. It is no freak—it has been created by the new leisure hours that people have obtained through the 40-hour week, a higher standard of living, and a desire to keep up with the neighbors. All of these things have created a market for products that can be used in a man's spare time.

The products with the greatest potential in this field are forest products, because they can be cut, sawed, nailed, and put together to make useful objects. The only drawback to forest products is that they are not readily available.

According to paint manufacturers, the do-it-yourself market is now absorbing 70% of their production. This did not happen overnight, or accidentally. The paint manufacturers developed a product that people could use easily and successfully. In the power tool industry, the multi-purpose bench tool had sales in 1948 of $2.25 million. In 1953, sales were $24 million. Single purpose bench tools—arbor saws, drill presses, band saws, and the like—increased from $15 million sales in 1946, to about $40 million in 1953. Portable electric tools—drill saws, sanders, polishers, routers, grinders, etc.—have zoomed from $6 million in 1946 to $95 million in 1953. These figures, still increasing, total nearly $160 million worth of power tools being sold annually to people to use on forest products.

Reaching the Market

Now, the question is, what is the forest products industry doing to make it easy for this vast army of men with saws, drills, etc., to buy wood products? Some steps have been taken that are working very successfully. The fir plywood industry is doing a tremendous job of consumer advertising and furnishes through its distributors complete sets of plans to make easy home projects; it has merchandised, through a handy-panel rack, small pieces of plywood that are small enough for the average do-it-yourself purchaser to carry in his car. However, many lumber dealers still do not cater to this business.

There are several large magazines not directly connected with the lumber business that sell patterns for home workshop projects. In other words, tremendous efforts are being made to sell lumber by everyone except the lumber people ourselves.

I am not proposing that the forest products industry, as a group, spend a lot of money advertising our product. Wood is a product that advertises itself very well. Many national magazines and newspapers with large circulations are constantly showing how to use wood products and the beauty of wood products.

The problem seems to be how to make it easy for people to purchase wood in a usable form, at a reasonable price, and at a price that will not be so mysterious. If we are going to broaden the base for the sale of forest products, we have to start thinking on

—Photo courtesy Edward Hines Lumber Co.

Display where customer can select paneling, molding, and other items will help boost retail sales of wood products.

[1] Presented at annual meeting of the Mid-South Section, FPRS, November 7–8, 1955, in Memphis, Tenn.

the consumer level. It will be well worth the effort, however, as the greatest new market for wood products is this vast group of people who now wish to buy our material and take it home with them to make useful objects. If the power tool industry is a $160 million industry, just think what the lumber market on the consumer level could be if properly promoted.

Make Buying Easy

This is a big problem, and to simplify it we must try to make it easy for a consumer to purchase our product. Wood products must be given wide distribution and be available in a great many places.

The first obstacle to be overcome before we start thinking about selling our product to consumers is the wood industry's lack of knowledge of size of this market. There are sufficient figures available from trade publications, government publications, and newspapers and other periodicals and this information should be properly publicized.

After we have aroused the enthusiasm of the wood industry, the next step will be to try and reach this new market. We should begin by removing some of the mystery from the definitions and terms that are applied to forest products. Lumber and forest products are cheap by the pound; perhaps we should start selling them, at least the small packages, by the pound instead of by the board foot. As a matter of fact, few consumers understand what a board foot is.

We should attempt to arrive at some uniform consumer grading standards so that grade of the wood product would indicate the purpose it is to serve rather than its commercial standard. Instead of No. 1 grade, we might use the word "utility"; instead of the A, B, and C grades, we might use the definitions of paint or stain grades; and for lumber that is perfect, we might do well to call it "perfect."

We should start thinking in terms of packaged material. Not many people would go into a lumber store and pick up a dirty board, especially a lady or gentleman who had on a nice clean suit. Packaging is so important today that many products are being sold where the value of the package exceeds the value of the product.

It is understandable that wood products eventually have to be sold through some kind of store or lumber dealer. It is understandable that our present setup on selling lumber will not be economical in serving this new market. Just as the old individual service grocery store with charge accounts, etc., has practically been replaced by the self-service system, we will have to handle our new consumer products through numerous self-service setups. Self-service does not necessarily require a complete change-over in our system of merchandising. A large percentage of self-service material can be sold through our present lumber and hardward dealers, by furnishing the dealers with merchandising aids, such as racks which hold consumer-size pieces of plywood and other wood products, packaged and plainly marked as to price and purpose.

Display units are being designed to act as silent salesmen for wood products or related items. They come in many different forms, designs, and sizes, but their purpose is the same. There are millions of products being offered on the American market today and the old system of high pressure salesmanship on the retail level is gone, because it is too expensive. These display units cost as little as $5 to $15. In other words, for a total cost of $5 you can hire a salesman who will work all year who will show no prejudice, has very little depreciation, never complains, and, used wisely, will sell a tremendous lot of products.

Nearly every important American industry that sells to the consumer, sells a large percentage of their products through the use of such display units. Any effort to sell wood products to the consumer on a large scale must use merchandising equipment such as this to be successful.

Many companies in the plywood and related lines are publishing brochures to stimulate this consumer market. Thousands of people have read these booklets, then gone to their lumber dealer and were disappointed at either his inability or lack of desire to furnish them with the product. It is not the lumber dealer's fault; it is unfair to blame the retailer for something the manufacturers and jobbers don't even have any conception of themselves. It is the fault of the whole industry and the correction must be started at the highest levels.

Market Study Needed

If there are any members of the Forest Products Research Society who agree that this market has a vast potential, I suggest that you form a small committee to study these statistics which deal with this do-it-yourself or consumer market. If it would be justified from the committee's findings, then determine how important this market is to the forest products industry. When these figures are added up, then perhaps it would be in order to set up a full scale committee to send out information to all members of the forest products business to suggest different ways and means by which they can reach the customer.

The consumer market is a market that no one can take away from you once you have captured it. In this respect, it is unlike all others. There is no substitute for the beauty of wood, and the ease with which it can be worked. The only substitutes are in the form of other things to do. If you make it hard for people to buy wood, they will play golf or use their leisure time in other ways. The whole object of merchandising is to make it easy for people to buy. People want wood so our problem is a simple one, but it will not solve itself.

Handbook for Small Sawmill Operators

How to Attain and Maintain Accuracy of Cutting

Part III. Mill Setup

K. C. COMPTON

State University of New York College of Forestry, Syracuse, N. Y.

and

G. E. BELL

Forest Products Laboratories of Canada, Ottawa, Ontario

Factors in setting up a small sawmill which may affect accuracy of cutting are discussed. Foundations under the sawmill are of prime importance in assuring properly cut lumber. Installation and adjustment of sawmill equipment to assure a stable mill setup is explained.

Foundations

IT SHOULD BE EVIDENT that the foundations under a sawmill are of the greatest importance in attaining reasonable accuracy of cutting. They should be made of materials which will absorb mill vibrations, and are readily available and comparatively easy to work. Any vertical, horizontal, or oblique movement of the mill foundations will result in miscut lumber, the seriousness of which will vary with the amount of movement.

At the time that the plans for the foundations are being drawn up, the mill owner should consider the height relationships of the headblock bases, the off-bearing rolls, and the edger. One good way to accomplish this is to set the edger feed table at a comfortable working height above the floor level and to plan the heights of lumber rolls, saw table, and headblock base to be progressively higher (Fig. 25). By this means, the flow of materials from the log deck through the edger will be orderly and without abrupt, labor- and time-consuming vertical movements. By planning the foundations with these arrangements in mind, the elimination of temporary blocking and shoring installed later will permit a more stable mill setup.

Permanent Mills

Many of the medium and heavier type of small circular sawmills now are located more or less permanently. In such cases they are frequently installed off the ground on poured concrete foundations. Plans for the necessary foundations are obtainable from the manufacturers of the individual mill being used (Fig. 26). Generally, the foundations should be at least 8 inches thick under the ways, and extend below the surface of the ground to 24-inch wide footings well below the frost line in the locality.

The insertion in the concrete foundations of well-embedded anchor bolts of sufficient size to hold the timber securely (one-half to three-quarter inch) is recommended. In order to allow for misalignment of anchor bolts and bolt holes in timbers, ordinary pipe larger by about one-half inch in diameter than the anchor bolts may be inserted over the bolts and in holes in the way timbers. The wooden way timbers can then be bolted directly to such concrete footings, but shimming will be ordinarily necessary underneath them to make sure they are perfectly level and straight.

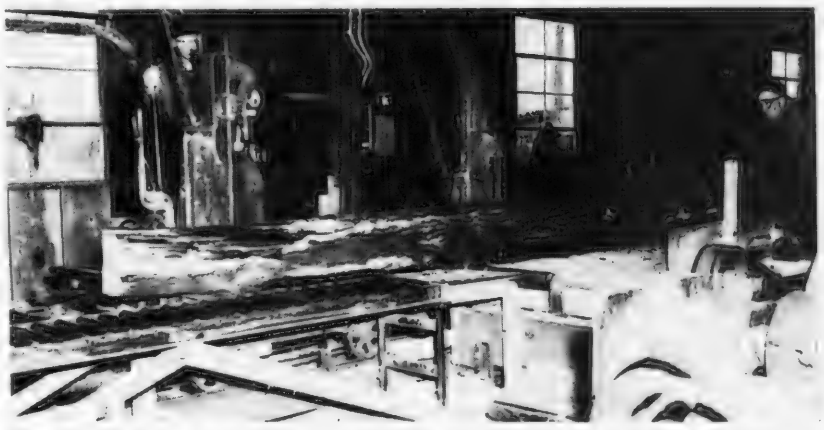


Fig. 25.—Well set up small circular mill. Note that top of carriage bolsters is above that of lumber rolls, and these are higher than edger table.

The Authors: Kenneth C. Compton attended Washington U., holds B.S. degree from Iowa State College, M.S. from New York College of Forestry. He was associated with Gulf States Creosoting Co., A. W. Williams Inspection Co., The Flintkote Co., and U. of Missouri before joining the New York forestry college in 1951. Gerald E. Bell received B.S. in Forestry from U. of New Brunswick in 1940, served six years as Canadian Army officer during World War II. He joined Ottawa laboratory as forest products engineer in 1946, was named head of Wood Utilization Section in 1952.

PREFACE

The Handbook for Small Sawmill Operators was prepared by the Logging and Milling Committee of FPRS at the request of Sectional Committee B–66 of the American Society of Mechanical Engineers.

The material has been divided into six parts being published serially in the Forest Products Journal. It will be available later as a separate bulletin from the Standards Department of ASME, 29 West 39th St., New York 18, N. Y.

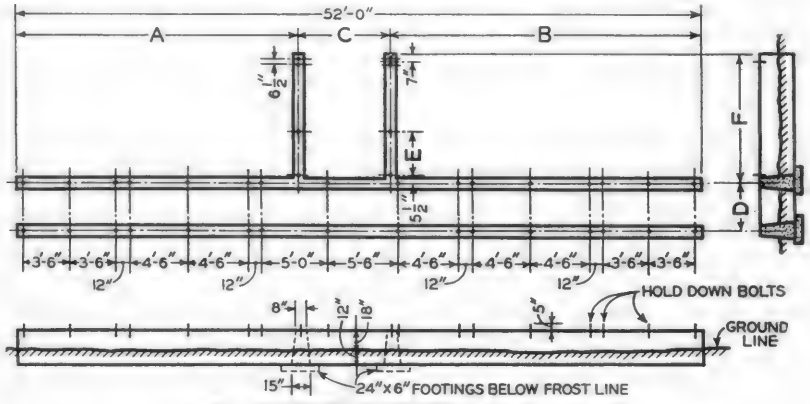
Publication of this Handbook by FPRS and ASME is not to be construed as establishing any new dimensional standards for lumber. Such standards are promulgated by the American Lumber Standards Committee for softwoods and by the National Hardwood Lumber Association for hardwoods. It is designed specifically to show the small sawmill operator how he can produce lumber to those standards more economically and most efficiently.

Acknowledgment is due many people, representing the several groups interested in the small sawmill business in various ways, for the constructive help and advice given in this handbook compilation. The Committee is very grateful to all those who helped so generously.

FRED C. SIMMONS, *Chairman*
FPRS Logging and Milling Committee

It is usually desirable that both the ways and any shims used be pressure treated with creosote or some other reliable wood preservative. If pressure-treated ways or shims are not available, then it is preferable to use woods of demonstrated natural durability, such as heart white oak, heart Southern pine, black locust, or cypress. Under no circumstances should green timbers be used. They will shrink during the drying process and cause the mill to be out of line.

Foundations under the husk should be similar in type, and properly situated in reference to the ways. A sawmill building can be erected around these foundations, on wooden pilings or concrete piers. The power unit can be mounted on the ground on its own poured concrete slab. (Fig. 27).



MILL CONCRETE FOUNDATION

MILL	A	B	C	D	E
NO.395	21'-6"	23'-6"	7'-0"	40¼"	36½"

MILL	MANDREL	F
NOS.395 &440	5'-2"	4'-2"

—Drawing courtesy Corley Manufacturing Co.

Fig. 26.—Plans for a typical poured concrete foundation for a small sawmill.

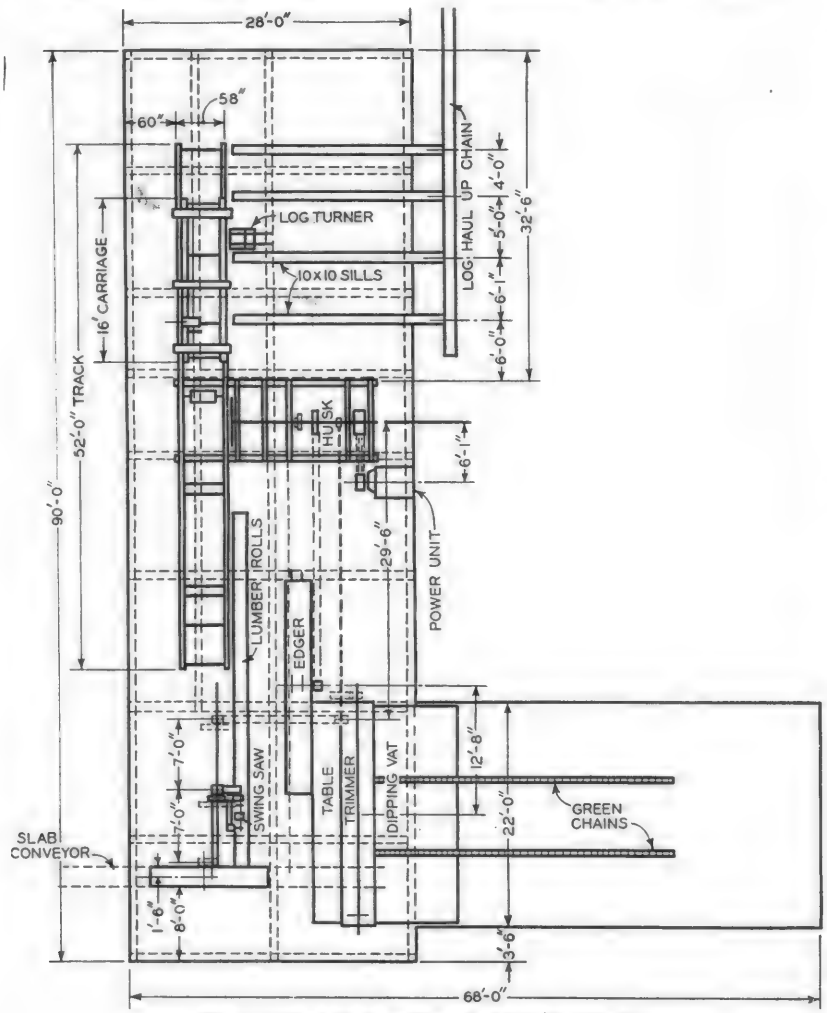


Fig. 27.—Plan for a medium sized circular sawmill.

A number of the newer electric powered mills have been erected entirely on a poured concrete slab, directly on the ground. The elimination of the need for belting and shafting between machines powered by individual electric motors has made this possible. Waste in such mills is usually conveyed out of the mill through a tunnel under the ways. In such construction the way ties and husk sills are bolted directly to the concrete, with shims underneath to make them level and true.

If the permanency of the location is not so well assured, the mill may be mounted on wooden pilings, of a durable species such as black locust, white oak heartwood, or pressure treated material, not less than 10 inches in diameter, set not more than 6 feet apart. At the front of the mill, and up to the saw, it is a good idea to space these piers 4 feet apart. Heavy joists, at least 6 inches by 8 inches, are bolted to the tops of these piers, and at least 3-inch thick plank flooring spiked over these. Again it is a good idea to have an internal combustion power unit, if used, on its own foundations, even though this is only a couple of pressure-treated skids on piers sunk into the ground.

In setting down the track, the track timbers should be well seasoned, with ample cross ties under them. With 6-inch by 6-inch timbers, 3-foot spacing is recommended for the cross ties, certainly not more than 4 feet. The track must be square to the husk sills and parallel to the husk frame. The track must also be perfectly level, and the guide track must be straight as well for its entire length. This can best be accomplished by using a chalk line. To straighten the track, bring a chalk line over the center of the guide track at one end, fastening the line to the bed timber, then take the line to the opposite end of the track, carry it over the center again, and down to a fastening on the bed timber. Draw the line tight, and then bring the entire track to the line.

One very important point should be kept in mind—while the mill may have been set up perfectly in the first place, the constant loading of logs, pull of belt, or softening of the soil, will often change conditions and a constant check should be made to insure alignment at all times.

Light to medium sawmills to be moved from place to place are frequently mounted on their own trailer wheels (Fig. 28). A welded steel

undercarriage for the mill is usually provided, so that the various elements are kept in proper relationship to each other. Frequently this is designed and braced like an upside down bridge truss. Jacks of various kinds are provided with these mobile mills to locate them firmly and level them up before they are put into service. This can frequently be done in as little as 30 minutes from the time they arrive at the new site. Adjustment of the mobile mill is similar to that of the portable mill, which follows.

Portable Mills

The older type of portable mill is transported to the new site partially disassembled and then set up on the ground (Fig. 29). The husk should be mounted on 10- by 10-inch sills bedded firmly in the ground to about half of their depth. These extend from the back of the husk and forward under the track location. A pit must be provided between these sills under the saw, for sawdust disposal, and this pit is bridged with 6- by 8-inch cross pieces directly under the ways, saddled between the extended husk sills. The remainder of the track can be mounted on 4- by 6-inch ties, embedded in the ground about 18 inches or 2 feet apart so that their tops are level with the husk sills.

On muddy or sandy ground, sills under the track ties are also desirable. The spacing of the ties under the track opposite the log deck should be closer than on the outfeed end of the mill. The rolling of logs onto the carriage and the turning of logs places greater stresses on these ties, and greater support of the trackway is necessary.

After the husk frame is firmly bolted to the sills, the mandrel and feedworks are set in place.

The carriage tracks are usually furnished fastened to light wood or metal stringers, with cross pieces to maintain the proper width between them (Fig. 30). Many mill manufacturers supply iron or steel brackets on the front of the husk (which bolt to the track stringers) to give the proper relationship between the husk and the track. Lacking this, the millman can bolt blocks to each husk sill of the correct size to maintain this relationship. The track stringers should be bolted tightly to the husk sills and way ties, and tested to make sure that they are exactly at right angles to the mandrel axis and level lengthwise and crosswise throughout their length. Finally, the carriage should be placed on the track and run slowly by hand forward and backward, testing with a level on the bolsters continuously to make sure that it remains level and true. If any dips or rises are found, the track ties should be trued up.

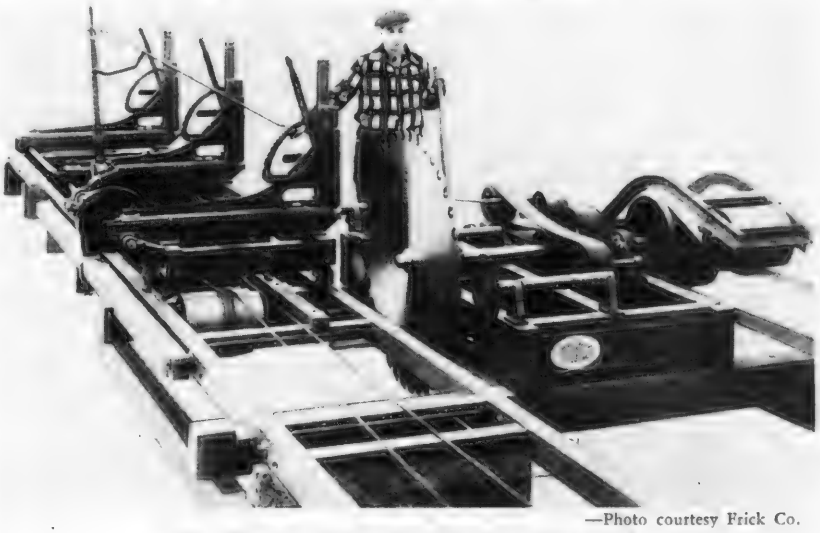
Most small mills have a cable feed, with the cable passing through sheaves near either end of the trackways, and around a drive drum on shaft extending from the husk. To install the cable properly, back the carriage alongside the log deck, carry one end of the cable underneath it and over the way cross timbers and attach it to the anchor bracket on the rear of the carriage. The other end of the cable should be passed through the sheave

—Photo courtesy Frick Co.

Fig. 31.—Carriage feed cable properly wrapped around shaft drum.

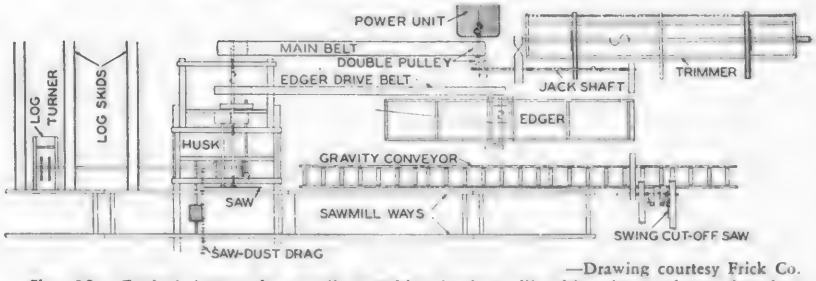
—Photo courtesy U. S. Forest Service

Fig. 28.—Trailer-mounted mobile circular sawmill.



—Photo courtesy Frick Co.

Fig. 29.—A portable mill set directly on the ground.



—Drawing courtesy Frick Co.

Fig. 30.—Typical layout for small portable circular mill with edger, trim and swing saws, all operated from single power plant.

at the opposite end of the ways, then brought back over and down under the drive drum. Give the cable four wraps around the drum, then bring the end over the drum and back through the sheave under the carriage (Fig. 31). The end should then be fastened to the anchor bracket at the front of the carriage. Any excess cable can be cut off after it has been adjusted and the mill is working properly. The cable should be tight enough to avoid slipping, or it may come off the drum.

Hanging the Saw and Adjusting the Mill

The next step is to hang the saw on the mandrel. The nut and loose saw collar are removed, and the saw eye slipped over the threaded end, over the lug pins and up against the tight collar. Before replacing the loose collar, twist the saw back so that it has a fair bearing on both lug pins. Then replace the loose collar and nut, tightening the latter with a wrench of a suitable size, never with a hammer and cold chisel.

Next test the hang of the saw on the log side by means of a straight-edge and plumb-bob. Saws tensioned to run at speeds greater than 600 r.p.m. can be expected to have a slight dish in them on the log side, but to stand perfectly straight when up to speed. Saws tensioned to run at speeds of less than 600 r.p.m. should generally stand perfectly straight when idle. If the saw is slightly dished, "papering" the collars can be done as a temporary remedy. However, if machine shop facilities are available, it is better to take the mandrel to the shop and have the collars faced perfectly true (See Fig. 8–A). If the dish still occurs when the saw is hung and tightened, it may be that the lug pins are binding, or have burrs around them. They should have just a little slack or play, and all burrs should be filed away.

If there is dish in the saw, the papering procedure can be followed as a temporary adjustment until the collars can be trued up, or the saw can be properly fitted. Cut a paper washer about ½ inch wide with the outside diameter equal to that of the saw collars, and another with the outside diameter equal to the inside size of the first one and the inside diameter equal to that of the saw eye. Oil both of these washers. If the saw is dished on the log side, put the big washer against the tight collar, the smaller washer against the loose collar, replace it and retighten the nut. Then test the saw with the plumb line for "dish" again. If it is still dished, another set or several sets of paper washers can be installed in the same way. If the dish is in the opposite direction, install the paper washers the other way around. Not all saws hang alike on the mandrel. When a different saw is hung, test for dish and repaper if necessary.

Finally, adjust the mandrel bearings for lead. A circular saw should lead slightly into the log to cut properly, and provide clearance on the gigback. Different saws require different amounts of lead, and the amount for each can be determined only by putting lead into the saw, sawing a few lines, and observing the results. For most purposes, use the least amount of lead that will prevent heating of the saw. This will insure a straight cut without the log rubbing on the saw on the gigback, and at the same time it will help to prevent the troubles that sometimes arise when cutting a wide face or burying the saw in the log.

Some mills specializing in cutting large cants use no lead and very wide clearances on the saw teeth. This is not recommended for the average circular mill cutting boards and dimension because of the great loss of wood in the form of sawdust which would result.

Because the amount of lead is a trial and error factor, it is suggested that lead of ⅛ inch in 20 feet is a good starting point, from which lead can be increased or decreased as needed. To do this, free the guide pins and run the carriage up so that one bolster is opposite the center of the saw. Then clamp a wooden stick to the top of the bolster so that it clears the blade by ⅛ inch. Back the carriage along side the log deck so that the bolster with the strip is 20 feet from the far edge of the saw, stretch a string between the rim of the far edge of the saw and the end of the stick, and adjust the mandrel bearings so that the front rim of the saw also just touches the string.

Lead should never be established by any other means than adjusting the saw angle by moving the mandrel. Putting lead into a saw by filing the teeth at an angle so that one side of the tooth is longer than the other will result in miscut lumber, because the guide pins are not designed to keep the saw in line under these circumstances. Putting lead into a saw by forcing it over with the guide pins will cause the saw to heat at the rim and dodge in the cut, resulting in miscut lumber. It will also damage the saw eventually, so this practice should also be avoided.

The saw guide should be as high as possible and still clear the bolsters on the carriage. The pins should be set to just clear the saw by the thickness of a piece of wrapping paper when it is standing still. Then, when the saw is up to speed, the guide should be adjusted so that neither of the pins touches the saw. Don't let them touch the base of the holders or case-hardening and cracking of the latter will be the result. The pins should clear the bottom of the toothholders by one-quarter to one-half inch.

The splitter, whether of knife or circular type, should be as close to the saw as possible, probably not over three-quarters of an inch away. Laterally, it should be set so that it is in line with the saw without binding against the log.

Installation of Accessory Equipment

This completes the installation of the sawmill headrig. Installation of accessory devices, such as log turners, sawdust and slab conveyors, edgers, trimsaws, dipping vats, etc., remains, although since they do not affect accuracy of the initial breakdown of the log they are outside the scope of this Handbook. The only effect of these devices on breakdown accuracy is the drain they put on the primary power source of inadequately powered mills, which has already been discussed in the section on machinery.

These accessory devices do have accuracy problems within themselves. It is important that the edger and the trimsaws do an accurate job of sizing, as well as the headrig. To accomplish this, these machines must be well set up, adequately powered, well maintained, and intelligently operated. Recommended positions of their location have been shown in the layout diagrams in this chapter.

More and more frequently these accessory machines are operated from their own independent power sources. This is particularly true in electric-powered mills, but the practice is also being followed in many mills powered with internal combustion engines. Excellent and compact air-cooled gasoline engines are now available, which are well adapted to furnishing power to edgers and trimsaws.

Waste conveyors are essential to the cleanliness and efficiency of the mill. Most frequently these are chain or belt conveyors. One or the other of these types is necessary for the coarse material. Sawdust may also be fed into such a conveyor, or it may be handled separately by a blower system.

More and more uses are being found for the "waste" from small sawmills so these conveyors and blowers now frequently lead to storage bins or processing equipment, rather than the old-time type of sawmill refuse burners.

A table of the power requirements of these accessory devices, and one on the power transmission ability of various types of flat and V belt drives, may be found in the Appendix of this Handbook.

Gluing Developments Related to the Navy's Shipbuilding Program[1,2]

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and

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Glued laminated construction has greatly increased the versatility and quality of wood construction. Laminates achieve higher quality and better design than is possible with solid material. Weaknesses are eliminated and dissimilar materials can be combined for a better product. Application of laminates in shipbuilding is discussed.

Introduction

THE FOREST PRODUCTS INDUSTRY is making ever-accelerated progress through research. This is certainly evident in the papers presented at FPRS meetings. It is also demonstrated in the volume of excellent material published in the Society's Journal, in commercial publications, and in the expansion of the wood products industries. The reason, of course, is obvious. Even though outlay for research and development today represents only a small fraction of product value, the field for development is so rich that it pays off many fold.

For the industry, its engineers, and technical representatives, it is increasingly difficult to keep abreast of the many technical developments. It is essential for the medium of the Society to take stock of recent developments, apply them to our needs, and to welcome progress.

It is the purpose of this paper to give a brief picture of some of the recent developments in the gluing field from the Navy shipbuilding viewpoint. This is offered as a continuation of previous papers on the subject presented before the Society and others (1), (2), (3), (4).[3]

Status of Marine Laminating

Marine laminating has progressed from a special art of the few to an established skill in the span of a few years. Reliable adhesives, facilities, technical specifications, and quality control methods have been developed. The country has the potential for producing, on a large scale, high quality laminates. These laminates have made possible greatly improved boat and ship construction. Through laminating, we can achieve higher quality and better design of members than with solid material (5). By laminating we can form lumber to shape, we can produce continuous long lengths without resorting to bolting cumbersome, strength reducing joints. By laminating we eliminate weakness produced in solid members which crack radially due to shrinkage. We can combine dissimilar materials, such as teak to fir, wood and glass reinforcements, and plastics.

The major challenger to marine laminating has been refractory species such as white oak. To consistently maintain marine service quality in large scale production of white oak laminates has required industry's ingenuity in finding ways to meet the requirements and principles laid down in military specifications and manuals. It has required development of knowledge of variables encountered in practical operations. It has required constant refinement of facilities, techniques, process inspection, specifications, and materials.

Refinements have been made in specifying adhesives and testing procedures. Adhesive manufacturers have cooperated in revising their adhesive bulletins. These bulletins have been clarified and standardized for marine laminating with particular reference to military specification processes. Adhesive inspection testing has been uniformly applied. The adhesive Qualified Products List was re-examined. Open and closed assembly time limits and curing conditions have been made a part of the qualification for each adhesive.

To aid laminators and shipbuilders in assuring product quality during fabrication, inspectors were trained in the details of determining adequacy of facilities, process inspection, and selection of samples. Laboratory testing was standardized by round robin tests to insure uniformity. Testing at origin was initiated to permit on-the-spot determination of quality by fabricators and inspectors. To provide for laboratory testing, equipment was set up at three major testing points in the U.S.A. and has been extended into overseas areas for Navy shipbuilding.

Laminating plants which have shown uniformly high quality production have been enabled to test at a lower level sampling plan and delamination testing is discontinued at the end of the second cycle if quality is acceptable.

For future production of marine laminates, laminator's facilities are being re-examined to assure that their capacity has remained intact. Where dismantling or cessation of production has occurred, current technical information can be furnished for re-establishment, should the need arise. The application of laminated materials in new ship designs is being encouraged to make full use of the advantages of laminating.

Prospects of expansion in laminating involve: first, the principle that laminated marine members are much superior to green, unseasoned solid members; the Navy should no more think of building emergency ships with green, solid timbers than to use improper welding procedures in steel ships. Second, laminators should search for new markets; for instance, recent developments in covered storage for wooden hulls open possibilities for utilizing laminated designs to protect wood craft from the weather. Steel and aluminum industries have immediately jumped in to offer a metal shelter. Shelters of laminated wood and preservative-treated wood could solve this problem not only for naval craft, but for thousands of yacht owners throughout the country.

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[1] Presented at Session VII, Glues and Gluing, FPRS Ninth National Meeting, June 21–24, 1955, in Seattle, Wash.

[2] The views expressed by the authors are not to be construed as representing those of the Navy Department.

[3] Numbers in parentheses refer to literature cited.

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J. G. Kuenzel is a graduate of U. of Minnesota and did graduate work at Yale U. He was associated with the Minnesota Forest Service, Minnesota and Ontario Paper Co., and U. S. Forest Service before joining the Bureau of Ships in 1942. He is presently Head, Wood Products Branch, Bureau of Ships.

Table 1.—PLASTIC IMPREGNATED WOOD
From PSNS Report E-279

Douglas fir—Resin	Impact		Horizontal Shear		Modulus of Rupture	
	Wet	Dry	Wet	Dry	Wet	Dry
	in. lb.		psi		psi	
Polyester	39	44	1275	1800	16,041	12,270
Untreated Douglas fir	48	48	882*	1340*	8,040*	10,033†
Epoxy	16	24	1014	2004	7,600†	10,220†
Phenolic	35	27.5	----	----	-------	9,800†

Resin	Dry Compression		Swelling %		Moisture Pick up %	Specific Gravity
	Parallel	Perp.	Tang.	Radial		
	psi					
Polyester	10250	2442	5.3	4.8	18.5	1.08
Untreated Douglas fir	7125	1093	7.6	5.6	59.2	0.54
Epoxy	----	----	3.8	2.5	38	0.91
Phenolic	----	----	4.83	3.61	41.4	0.72

*Fir values taken from FPL tables for small, clear specimens. "Dry" values are for 12% Moisture Content.
†Values from 1 sample.

Closely tied to the future of laminating is our progress in research. Increasing effort in research and development of wood products is being carried out in cooperative programs of the Bureau of Ships with industry, institutions, and laboratories. This effort is due to increased demand for technical information during the course of design, material selection, and production. To encourage pioneering in radically new development and to encourage leadership in this country in wood as an engineered product should be our objectives.

During the past year, work at several laboratories in the field of adhesives for wood laminating has included:

(a) investigation of assembly time limits;
(b) curing schedule ranges;
(c) analytical test methods for adhesives;
(d) gluability of species for wood decking, such as hickory and foreign woods;
(e) development of faster quality control tests; and
(f) gluing of wood treated with preservatives and with plastics.

Prospects are favorable for decreasing the time period and expense of quality control testing through intensifying the conditions of the twelve-day delamination test. In this way, it may be possible to reduce the test period considerably.

In laminating oak and hickory, definite minimum closed assembly times as well as maximum times have been found necessary before assembly pressures can be applied. This appears to be a function of absorption and evaporative rates.

Analytical tests hold a key to progress in the development of adhesives. Present tests are limited in value and shed little light on the bonding properties of polymers. In the direction of exploring the effect of molecule size of polymers on adhesive properties, a method (6) employing selective precipitation in hexane has been investigated. An immediate use of a method of this type would be in determining the time at which an adhesive has exceeded its useful storage life by gradual polymerization.

New adhesives, such as epoxy types, are being explored for wood bonding. As distinguished from water borne phenolics, these adhesives are 100% reactive. They shrink only during the gel stage and therefore do not require follow-up pressure. They are insensitive to assembly times and can be adjusted to a wide variety of curing conditions. To date these resins are not practical for laminating, but they do point to what may be expected in the future. At present, these resins when combined with reinforcing glass fibers are challenging the small boat field in the form of molded plastic hulls. However, they are offering the possibility of combining the best features of wood and plastics in such ways as plastic-covered plywood boats and plastic-surfaced panels for reduced maintenance combined with improved appearance.

An interesting combination of plastics and wood was explored last year in the form of polyester impregnated wood decking (7). In aircraft carrier decking, the short span together with the depth of section results in horizontal shear strength being the critical design factor. Experiments in impregnating Douglas-fir with polyester plastic indicated horizontal shear strength increased as much as 50% together with improved hardness and wear resistance (Table 1). In treating approximately 1200 lineal feet of this decking for trial ship installation, an unprecedented problem presented itself in handling a mass of approximately 5000 pounds of catalyzed resin in the pressure tank. If this resin started to cure en masse, the exothermic reaction would be enormous as known from similar experiences with only gallon masses. Since this amount had to be maintained over a period of a week in the pressure tank to impregnate all the decking, we ended up by surrounding the resin with cold water, using an inert gas for pressure, and reducing the temperature over the weekend with dry ice. Also included in this experimental decking series were Enrup-surfaced vertical laminated hickory and glass plastic-surfaced fir decking.

Conclusions

Glued laminated construction has greatly increased the versatility and quality of wood construction. However, it has opened the door to even wider possibilities. Through laminating we can achieve 100% preservative treatment by impregnation of laminates before gluing. This eliminates the decay objection to wood and, as such, is as important to the wood industry as if the corrosion problem were solved in the metals industry.

Acknowledgment

Grateful acknowledgment of contributions to work referred to in this paper is made to colleagues on the staff of the Research Laboratory of Puget Sound Naval Shipyard, the Wood Products Branch of the Bureau of Ships, and the several laboratories participating in programs cited, including especially, Gamble Brothers Inc., U. S. Forest Products Laboratory, and Timber Engineering Company.

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Discussion

Q.: Is the aircraft carrier Roosevelt's steel flight deck indicative of a new trend?

Mr. Miles: At the time they were faced with a problem for which there was no immediate solution. We were required to meet a weight limitation at the time as far as wood decking was concerned. Steel in the landing area was an interim measure which raised the weight limitation. The remaining part of the deck is wood.

A. H. Rauch (Plywood Research Foundation): What difficulties were encountered in impregnating wood with epoxy resins? Were polyesters used primarily?

Mr. Miles: These resins do what you might think, that is, they coat the wood fibers rather than penetrate the cell wall itself as compared with phenolic resins. We couldn't get complete impregnation of solid fir with poyester resin. Lamination gives the answer. When laminae were reduced to ½ inch, they received 100 per cent impregnation. We were using standard impregnation techniques. The epoxy resins are normally very viscous. They are thinned with solvent. After impregnation, removing solvent is a problem with present epoxy resins.

Q.: Is there a reduced testing time for laminates from the 12-day period?

Mr. Miles: One reduction was made. The standard 12-day test involves three cycles. We have gone to two cycles only at 5 per cent delamination upper limit. There is a terrific advantage in a delamination test which would give an answer in two or three days' time. Work done in the direction of reduced cycles is very worthwhile. We are interested in the possibility of increasing water pressures to reduce the soak cycle and reducing relative humidity to shorten the drying cycle.

M. H. Estep (American–Marietta): What was the rate of loading the Douglas-fir block shears in Table 1?

Mr. Miles: 0.025 in/min. ± 25 per cent.

Strength and Elastic Properties of Two-Species Laminated Wood Beams[1]

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Describes method of determination and form factors obtained for use with transformed moment of inertia design calculation of two-species laminates with a depth of two inches. Calculated were modulus of elasticity, modulus of rupture, and fiber stress at proportional limit.

GLUED LAMINATED BEAMS for structural uses are customarily made from one species, commonly of just one grade of that species. Where more than one grade of a single species is used in a laminate, present design specifications recognize that the better grades should be used in the faces, the areas of high stress concentrations. When so used, the laminate often is considered to be designed of the higher stress grade only.

Although grade combinations extend our utilization of wood products to some of the lower grade classes, only species of high strength and elastic properties are used. Two-species laminates, made of lower strength materials in low stress areas of structural assemblies, could provide markets for many species which used alone are not now considered satisfactory.

Methods of calculating the strength properties of two-species combinations have been developed, related to the transformed I-beam cross-section principle used for composite beams not of wood. This study was developed in an attempt to isolate any form factors necessary to two-species laminate design calculations. This was done through the use of several species combinations in which the core material as well as the several face thicknesses for each species combination remained the same. The term "laminate" as used in this study refers to a glued wood construction with the grain of all the pieces parallel to one another, designed primarily for strength and utility.

When woods of the same density and/or approximately the same strengths are laminated into a structural member, the design problems are the same as for a solid member. The assumption that modern glue bonds are at least as strong as the joined materials eliminates any consideration of reduction in allowable stresses in laminates.

A comprehensive study by Newlin and Trayer first published in 1924 developed for the first time certain stress value correction factors depending on the shape of the cross section, to be used in calculating beam strengths, and called these factors "form factors" (12, 13).[2] In 1941 McKean completed a study of the mechanical properties and design procedure for two-species laminated beams which was published in 1944 (10). McKean utilized a method of design known as the transformation theory, in which the rectangular two-species laminate was considered to have, in effect, an I form.

Dietz, in a study of strain distribution in solid Douglas-fir beams, confirmed the general features of the Newlin–Trayer theory (13) in addition to demonstrating several other relationships (3). It was shown that beam sections plane before bending apparently are not plane after bending, an assumption usually used to facilitate the demonstration of stress distributions, and that deviation from the plane increased with increasing bending moment. Investigation of such deviations in two-species laminates might possibly clarify stress distributions now assumed.

In 1944 a collaborative bulletin was published on the design of wood aircraft structures (6) which included a formula later demonstrated to be of satisfactory use in the analysis method for modulus of elasticity of sandwiches (16). For two-species laminates this is expressed:

$$E_a = \frac{E_f I_f + E_c I_c}{I}$$

where:

E_a = effective modulus of elasticity of the laminate, psi
E_f = modulus of elasticity of the face, psi
E_c = modulus of elasticity of the core, psi
I = moment of inertia about the center line of the cross section

[1] A contributed paper.

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[2] Numbers in parentheses refer to literature cited.

Table 1.—STRENGTH AND ELASTIC PROPERTIES OF WOODS USED IN TWO-SPECIES LAMINATES

Species	Specific Gravity (Oven Dry Vol.)	Static Bending		
		Fiber stress at proportional limit psi	Modulus of Elasticity 1000 psi	Modulus of Rupture psi
Cordia alliodora	0.48	8,170	1,510	12,180
Loxopterygium sagotii	0.62	9,900	1,750	13,660
Magnolia sororum	0.56	9,600	1,970	14,250
Astronium graveolens	0.94	11,320	2,230	16,620
Caryocar villosum	0.84	10,990	2,160	17,060
Bagassa guianensis	0.76	13,900	2,580	20,050
Manilkara bidentata	1.03	15,030	3,450	27,280

perpendicular to the face grain of the beam, inches⁴

I_f = moment of inertia of the face about the neutral axis, inches⁴

I_c = moment of inertia of the core about the neutral axis, inches⁴

In 1944 Poletika and Martin presented a formula for determining the limiting minimum thickness of the face laminae to avoid failure due to overstressing of the core (16) which has subsequently been used in several investigations of two-species laminated beams (4, 5, 21). In 1948 Dietz completed two papers relative to laminated beams of two species. The first was primarily concerned with quality of materials which could be utilized in beams in relation to amount and location of stresses (4). The second described an engineering theory of two-species laminated beams in its entirety (11). The use of the transformed section and the development of face-core ratios are similar to those already described (10, 16, 21). The calculation for shear is obtained through an adaptation of the conventional formula for shear in which the transformed moment of inertia and statical moment are used. A valuable design formula for calculation of the horizontal shearing stress intensity in two-species laminates is also given.

Fabrication of Test Specimens

All of the woods used came from the American tropics. Individual species were selected on the basis of relative strength and elastic properties appropriate to the design of the experiment. The core material was *Cordia alliodora.* This and the six face materials are listed in Table 1 with pertinent information about each species (20).

The material had been air-dried for several months before selection for this problem and was further air-dried before sawing. When the moisture content had reached approximately 18 per cent, it was cut into lamination blanks, 2½ inches wide by 36 inches long. From each end of the lamination blanks a specific gravity specimen was cut and the specific gravity obtained by the conventional immersion method based on oven-dry weight and oven-dry volume. As a major part of this investigation involved the relationships among groups of comparable beams, it was necessary that the cores of all beams be as nearly alike in strength properties as possible. Specific gravity was the best available indicator for this purpose (9). Specific gravities as determined for the *Cordia* varied from 0.330 to 0.530. The cores in their ultimate form were 1, 1¼, 1½, 1¾, 1⅞, and 1-15/16 inches in thickness, with 5 beams in each thickness group, and a complete set of thicknesses for each of the 6 face species, a total of 180 cores.

In each thickness classification of 30 cores it was possible to group the material with 12 cores below 0.445 and 18 cores above 0.445 specific gravity. To avoid biased selection, random number distribution was then used to divide each thickness group of 30 cores into the 6 face species groups. The result was a maximum difference between face-thickness averages of 0.023 and between species averages of 0.010 specific gravity. Face ply species were selected on the basis of strength properties and were not segregated by specific gravity.

Tests on three coniferous species have shown no significant differences in bending strengths whether the load was applied to radial or tangential face (9). Wangaard and Poletika have shown that the growth ring placement in red oak beams laminated of two pieces with different specific gravities has no significant effect on the strength properties (21). It was felt that if this were true of a ring porous wood it would apply to the more homogeneous tropical species of this problem. Therefore, the laminations were examined and matched solely to obtain in each thickness-face species group several beams of all flat-grain laminae which could later be subjected to service tests. Remaining face and core laminations were not segregated on the basis of growth increment orientation.

The core material had been satisfactorily end trimmed at the time the specific gravity specimens were removed and it was not necessary to retrim the blanks. They were first squared on one corner on a 6-inch jointer. Rate of feed was slow and ordinary high speed steel knives cut satisfactorily. The blanks then were planed to desired thickness on a 12-inch single cutter-head planer. For this material ordinary high speed steel knives produced good gluing surfaces. Synthetic adhesives, as used in this problem, do not produce good bonds without close contact (15), and a thickness tolerance of ± 0.005 inch was maintained.

The face species presented a problem in laminae preparation due to the extremes in density and the grain structures peculiar to some of the species. With the three face materials *Magnolia, Bagassa,* and *Loxopterygium,* high speed steel knives with no special grinding were satisfactory but with the other three species gluing surfaces were poor. Previous investigations have shown varying results with the use of knives with back bevels of 25 degrees and front bevels of 35 degrees (17, 19). High speed steel knives with these bevels were tried and produced more satisfactory surfaces but the life was short. Special knives were obtained, in which the whole blade, not just the cutting edge, was tungsten carbide and these knives produced good gluing surfaces without requiring sharpening.

The adhesive used was a two-component resorcinol-phenol-formaldahyde resin. A sufficient quantity was obtained from a single manufacturer's batch to insure equality of adhesive throughout the specimens. The extreme variations in specific gravity of the species in this investigation complicated the problem of minimum adhesive spread to produce a good bond. To eliminate possible variables among beams, a spread of 60 pounds per thousand square feet of glue line was used in all cases. The adhesive was spread by machine, with an open assembly time of 6 to 8 minutes and a closed assembly time of 20 to 24 minutes. The test specimens were glued at a pressure of 200 psi applied through a series of 6 rocker-head clamps distributed over the 34-inch length of the rough beams. The adhesive was cured 8 hours at 150° F. in a conditioning chamber where relative humidity and temperature were controlled. The approximate curing time was calculated by the method developed by McLean (8) and the results were compared to actual measurements made by thermocouple and potentiometer. Curing temperature was reached by actual measurement about 60 minutes before the calculated time elapsed.

After a one-week conditioning period, the specimens were machined to test size. The beam faces of 1/16-inch

and 1/32-inch had been fabricated at 1/8-inch and it was necessary at this time to reduce them to the desired thickness. Before gluing, the thickness of each face lamina had been determined by micrometer measurement at three marked places and recorded on the beam for reference at this time. The whole beam was now measured at these locations. Desired face thickness was subtracted from total beam thickness. The beam was then planed so that face A was reduced to desired size. The process was repeated for face B and the desired face thicknesses obtained. Planer cuts during this operation were never greater than 0.006 inch and measurements were taken after each cut to avoid destruction of the specimens.

Testing Procedures

In general, the testing followed procedures prescribed by the American Society for Testing Materials (1). All cross-sectional dimensions were measured with a micrometer to an accuracy of 0.001 inch. The length of all specimens was measured to an accuracy of 0.01 inch with a steel rule. Immediately after every test a specimen 1-inch wide was cut from each member. With the exception of the 1/32-inch face group, the faces were then cut from the core with a fine saw and all adhesive removed. The specific gravity of each sample was obtained by the conventional immersion method based on oven-dry weight and oven-dry volume. The moisture content of all pieces at time of test was calculated. All of the tests were made on a Tinius Olsen 10,000-pound mechanical machine.

Block shear specimens were used to test the glue joints and were composed of two laminae and one glue line. Since the thickest face lamina was 1/2 inch, it was necessary to modify the standard specimen to a balanced form with faces of this thickness. Two shear specimens were tested from each face-species group Type A beam, Fig. 1, a total of 60 tests. Average shear strength was 1595 psi with 92 per cent wood failure by ocular estimate.

Analysis and Theory

In view of the fact that other methods, involving factors unknown about the species tested might be adapted to the calculations of two-species beam properties (2, 11), the discussions and conclusions herein reported relate only to the methods used. From the data recorded for each beam, modulus of elasticity, modulus of rupture, and fiber stress at proportional limit were calculated in the usual manner. Horizontal shear was calculated by the modified formula using statical moment and moment of inertia of the transformed I-section. For convenience in later calculation, actual maximum bending moments were also obtained.

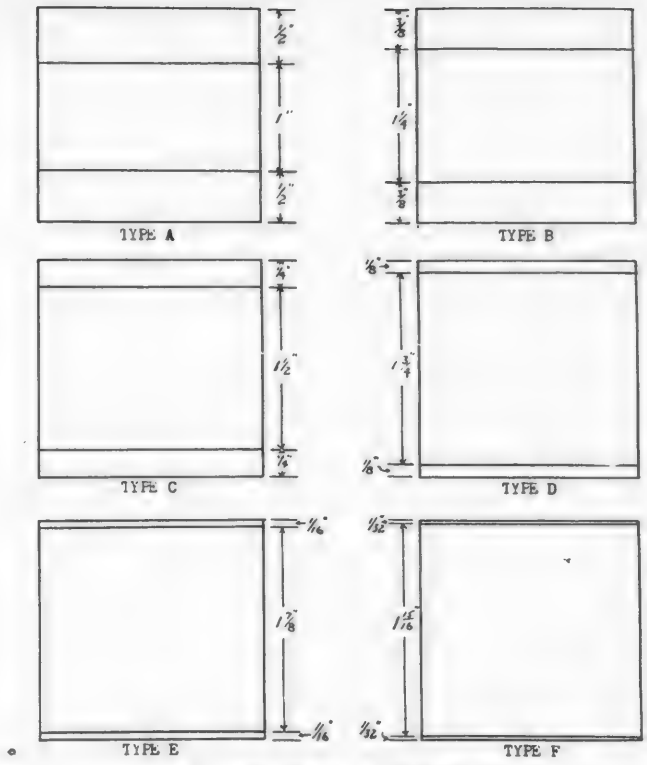

Fig. 1.—Cross sections of laminated beams.

Calculated results for modulus of elasticity: In a previous study of two-species laminates (10), the test values for modulus of elasticity were corrected to 12 per cent moisture content values by use of converting factors determined at the U. S. Forest Products Laboratory (9). It is questionable if this procedure is completely valid in two-species laminates, particularly if the faces and core are of different moisture contents, however slight. No such converting factors are presently available for the tropical species involved in this study. It was decided that the most reasonable method of handling these data would be to correct all published strength values for the individual species involved.

Investigation has indicated that if form factors are necessary for two-species laminates, they may be required for some strength properties but not for others (5). Accordingly, it was decided to compare test or actual values with calculated values for the three properties: modulus of elasticity, modulus of rupture, and fiber stress at proportional limit. The first calculated value considered is modulus of elasticity, obtained by the formula previously cited (6, 16). Before substitution was made in this formula, the published values of the moduli of elasticity for core and faces were corrected to specific gravity and moisture content at time of test. The moments of inertia for the faces and for the core were determined by the subtraction method.

Discussion and conclusions—modulus of elasticity: The actual moduli of elasticity are not equal to the calculated moduli of elasticity. It is not apparent from these data whether the disagreements are due to the variations in face stiffness or the differences in face thickness. To facilitate examination of the data, the ratios of actual to calculated moduli were obtained for all beams. In order to evaluate the significance of the variation among face thickness groups and among face stiffness groups, these ratio data were examined statistically by means of analysis of variance.

The F values indicate that significant differences exist among face species groups and none exist among face thickness groups. The next step was to evaluate which of the species means differed significantly from the remainder. This was accomplished through the use of the "t" test of significance. It was determined that the mean for group II, with face of *Loxopterygium sagotii,* is significantly different from all of the other means and that none of the remaining means are significantly different from each other. Since the face species used varied in order of increasing stiffness or strength depending on the property under discussion, Fig. 2 is a graphic illustration of

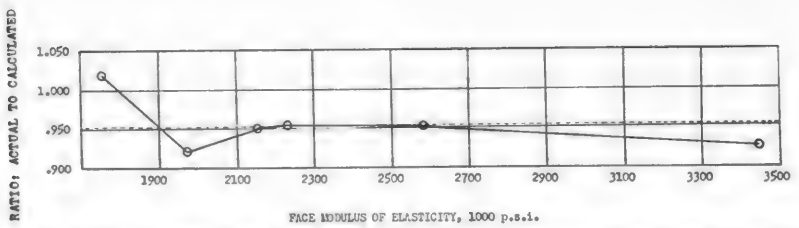

Fig. 2.—Effect of core and face stiffness on ratio of actual to calculated modulus of elasticity.

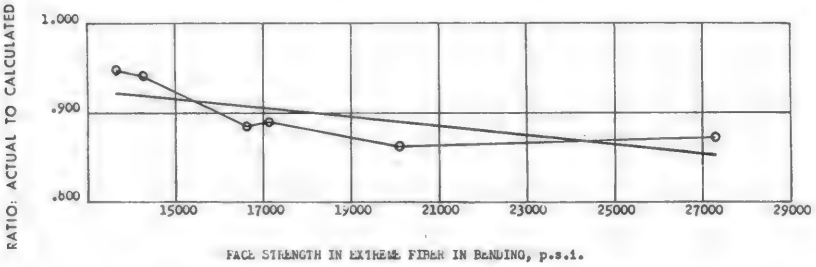

Fig. 3.—Effect of face strength in extreme fiber in bending on ratio of actual to calculated modulus of rupture.

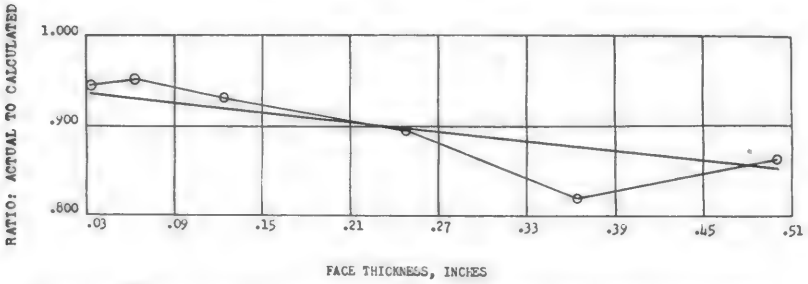

Fig. 4.—Effect of face thickness on ratio of actual to calculated modulus of rupture.

the distribution of the ratio means plotted in relation to moduli of elasticity.

By the method of least squares, a straight line was fitted to these data and an analysis of the slope of this regression line was made. This analysis shows there is no trend in the modulus of elasticity ratio data as the stiffness of the face material varies. For any change in the face stiffness there is no significant change in the ratio of actual to calculated modulus of elasticity and this value may be expressed by the average of the ratio data, 0.954.

It may be well at this time to review the relationships as shown in Fig. 2. The x-axis of the graph shows the stiffness of the face material expressed as the modulus of elasticity and, since the core material for all beams is the same, might also be expressed as the $\frac{E_f}{E_c}$ ratios. The y-axis is the ratio of actual or test modulus of elasticity to calculated modulus of elasticity. At 1.000 on the y-axis, the actual and calculated values are equal. The average ratio value of 0.954 indicates that the test values were 4.6 per cent less than the calculated values. For any two species laminates with $\frac{E_f}{E_c}$ ratios within the limits of these data, the difference as shown may be used as a correction factor in the formula

$$E_a = \frac{E_f I_f + E_c I_c}{I}(0.954)$$

where the symbols are as previously explained and 0.954 is the correction factor.

Calculated results for modulus of rupture: To obtain the calculated modulus of rupture for the beams of this study, a determination of calculated maximum load (P) would have to be made. However, since actual and calculated moduli of rupture have the same relationship as actual and calculated maximum bending moments (7, 21), the bending moments were studied in respect to this strength property. The general relationship (7) between bending moment induced by a load applied to a beam and the extreme fiber stress developed is given by the flexure formula. A two-species laminated beam is considered analogous to an I-beam (5, 10, 21) and the values for the moment of inertia used in the flexure formula were modified accordingly. The moment of inertia of the two-species I-beam section is obtained by modifying the usual I-form equation. This equation would be for the width of the transformed flange whereas in reality the face is considerably narrower and the stresses would be higher than indicated. Modification is accomplished (10) by multiplying the equation by the ratio $\frac{E_c}{E_f}$

so that $$I = \frac{bd^3}{12} - \left[\frac{(b-w)\,d_1^3}{12}\right]\frac{E_c}{E_f}$$

where:

- b = actual beam width (w) multiplied by the ratio of the modulus of elasticity of the face (E_f) to the modulus of elasticity of the core (E_c), inches
- d = depth of beam, inches
- w = width of beam, inches
- d_1 = depth of core, inches

Moments of inertia calculated by this equation may then be used in the flexure formula for two-species combinations. In addition, all published values for maximum fiber stress of the face species were corrected to test moisture content and specific gravity. The actual average bending moments for each five replications and the calculated average bending moments were obtained.

Discussion and conclusions—modulus of rupture: The actual and calculated maximum bending moments are not equal. It is not apparent from these data whether the disagreements are due to the variations in face strength or the differences in face thickness. The ratios of actual to calculated moments were obtained for each beam to facilitate statistical examination. In order to evaluate the significance of the variation among face thickness groups and among face strength groups, these ratio data were examined by analysis of variance. Twelve beams in various face thickness and face species groups had failed in shear during testing. To maintain orthogonal sub-groups in the analysis, the ratios for these beams were replaced by missing plot technique and suitable correction for degrees of freedom was made. These supplied items have no effect on the error of estimate if the degres of freedom are deducted in this manner (18). However, the treatment mean square is biased upward so that the F-value tends to be exaggerated. The best significant F should be nearer to the 1 per cent than the 5 per cent point under these conditions and this was true throughout the analyses.

The F values indicate that significant differences exist among face species groups and also among face thickness groups. Using the "t" test, it was determined that the means for groups I and II, with faces of *Magnolia sororum* and *Loxopterygium* [illegible] were significantly higher than the remaining means but not significantly different from one another. By the

Table 2.—MODULUS OF RUPTURE CORRECTION FACTORS

Per Cent Core Depth To Total Depth	Ratio $\frac{f_c}{f_f}$ 0.950	0.900	0.850	0.800	0.750	0.700	0.650	0.600	0.550	0.500	0.450	0.400
0.98	0.982	0.978	0.973	0.969	0.962	0.955	0.947	0.938	0.927	0.914	0.898	0.881
0.97	0.979	0.975	0.970	0.965	0.959	0.952	0.944	0.935	0.924	0.911	0.895	0.878
0.96	0.977	0.973	0.968	0.963	0.957	0.950	0.942	0.933	0.922	0.909	0.893	0.876
0.95	0.974	0.970	0.965	0.960	0.954	0.947	0.939	0.930	0.919	0.906	0.890	0.873
0.94	0.972	0.968	0.963	0.958	0.952	0.945	0.937	0.928	0.917	0.904	0.888	0.871
0.93	0.969	0.965	0.960	0.955	0.949	0.942	0.934	0.925	0.914	0.901	0.885	0.868
0.92	0.967	0.963	0.958	0.953	0.947	0.940	0.932	0.923	0.912	0.899	0.883	0.866
0.91	0.964	0.960	0.955	0.950	0.944	0.937	0.929	0.920	0.909	0.896	0.880	0.863
0.90	0.961	0.957	0.952	0.947	0.941	0.934	0.926	0.917	0.906	0.893	0.877	0.860
0.85	0.949	0.945	0.940	0.935	0.929	0.922	0.914	0.905	0.894	0.881	0.865	0.848
0.80	0.937	0.933	0.928	0.923	0.917	0.910	0.902	0.893	0.882	0.869	0.853	0.836
0.75	0.925	0.921	0.916	0.911	0.905	0.898	0.890	0.881	0.870	0.857	0.841	0.824
0.70	0.912	0.908	0.903	0.898	0.892	0.885	0.877	0.868	0.857	0.844	0.828	0.811
0.65	0.900	0.896	0.891	0.886	0.880	0.873	0.865	0.856	0.845	0.832	0.816	0.799
0.60	0.888	0.884	0.879	0.874	0.868	0.861	0.853	0.844	0.833	0.820	0.804	0.787
0.55	0.876	0.871	0.866	0.861	0.855	0.848	0.840	0.831	0.820	0.807	0.791	0.774
0.50	0.863	0.859	0.854	0.849	0.843	0.836	0.828	0.819	0.808	0.795	0.779	0.762

same test it was determined that the moment ratio mean for the 0.375-inch face group was significantly lower than all the other face group means and that none of the remaining means was significantly different from one another. Figs. 3 and 4 illustrate the mean relationships tested. To each group of data, a straight line was fitted by the least squares method and the slope of each regression line examined. The significant F values in both analyses indicate a trend in the maximum bending moment ratio data when the face thicknesses vary and when the face strengths vary.

The next tests were to determine if the straight line was the best fit of the data, or if there was any evidence of curvilinearity. The non-significant values for F in both analyses for scatter of the means about the regression lines indicate that there is no evidence of curvilinearity of the data (18).

Although several characteristics of these data have been observed, this analysis provides no practical method of application unless the face thickness and face strength of other beams should coincide with those of this study, which is highly improbable. Therefore, these data were further examined by a multiple regression study to evaluate the mutual relationships of the variates. The results are summarized by

$$y = 1.061 - 0.2469X_1 - .00000589X_2$$

where:

- y = ratio of actual to calculated maximum bending moment
- X_1 = face thickness, inches
- X_2 = face strength (Modulus of Rupture), psi

and 1.061 is a constant.

The significance of the multiple regression as an entity was next tested. Using F, it was determined whether the mean square due to regression was significantly greater than that unexplained by regression. The highly significant value for F obtained is sufficient evidence that fiducial statements may now be made about the dependent variable, the regression coefficients, and the regression (18).

As was noted previously, deviations of calculated moduli of rupture from actual or test moduli could be corrected only for beams identical to those used in this study until the results of the regression equation were available, and their significance determined. Table 2 was prepared using values from that equation and provides correction factors for calculated results obtained with any combination of face thickness and face strength. The columns of the table are ratios of core strength to face strength and the lines are core percentages of total beam depths. Some selectivity is now available through the use of Table 2 but application of these correction factors (F) should be limited to beams of the same depth as those in this study, two inches. Newlin and Trayer have shown that rectangular beams of different depths required a correction factor (F′) related to strength or stiffness of test specimens two inches deep of the same material (13). Although these factors (F′) were developed for beams of one species, they are based on the accepted theory of support of underlying fibers (3, 5, 13) and it is reasonable to believe they will apply to two-species laminates.

In the design calculation of maximum bending moment for a beam limited in strength by fiber stress in the surface fiber of the face and not by fiber stress in the core or shear in the core, these correction factors (F, F′) would be used with the flexure formula so that $M = \frac{SI}{c} \cdot F \cdot F'$ where:

- M = maximum bending moment, pound-inches
- S = stress in extreme fiber in bending, psi, of face material
- I = modified moment of inertia, inches^4
- c = one-half depth of beam, inches
- F = correction factor from table 2
- F' = correction factor from reference 13.

Values obtained may be used to calculate load supporting ability of the beam, the determination of which is dependent on the type of load involved and need not be discussed further at this time.

Calculated results for fiber stress at proportional limit: The calculated values for fiber stress at proportional limit were obtained by the same method as described under modulus of rupture. In the flexure formula the published values for fiber stress at proportional limit were used after correcting to test moisture content and specific gravity.

Discussion and conclusions—fiber stress at proportional limit: As with the other properties, actual and calculated values do not agree. Because of the method by which this property is determined, it is subject to the greatest variation and error of any of those studied. The ratios of actual and calculated moments were obtained and examined by analysis of variance to evaluate the significance of the variation among face thickness groups and face strength groups. The values for F obtained in this analysis indicate that significant differences exist among face species groups but none exist among face thickness groups. Examination of the group means by use of the "t" test showed that the groups II, IV, and V, with faces of *Loxopterygium sagotii, Caryocar villosum,* and *Bagassa guianensis,* respectively, were not significantly different from one another and that the other three means were significantly different from these three and also from each other.

The distribution of these means is shown in Fig. 5. The regression of these data was studied and it was found to be not truly linear. The slope indicated a trend as the fiber stress at proportional limit strength of the faces varied but the means were scattered. Attempts to fit exponential, parabolic, and hyperbolic types of curves to the data were equally unsuccessful. An extensive polynomial could un-

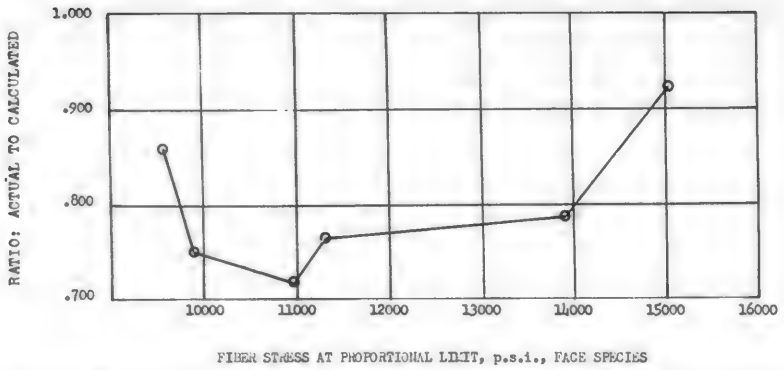

Fig. 5.—Relationships between actual and calculated fiber stress at proportional limit.

doubtedly have been fitted to these data but there is no logical explanation for such a curve. This variability in fiber stress at proportional limit is not unusual. In the determination of basic stresses it was recognized at an early date that fiber stress at proportional limit is not as reliable as modulus of rupture because of the personal element in the determination of the former, the considerable error resulting in proportional limit values from slight inaccuracies in deflection measurement, and the effect of defects on the determination of the stress (14). It is possible that all of these items contributed to the results as shown in Fig. 5.

In Fig. 5 the y-axis represents the ratio of actual to calculated bending moment at proportional limit, and $y = 1.000$ values would indicate that the results of calculation are equal to test results. Although no general expression of the relationship between the means could be established, it is apparent that they are all less than 1.000. The mean of the ratio data is 0.7975, indicating that the test values were 20 per cent less than the calculated values. The x-axis of Fig. 5 is the fiber stress at proportional limit of the face material. Since all of the beams contained the same core material, it also represents ratio values of fiber stress at proportional limit of the core to fiber stress at proportional limit of the face material from 0.908 to 0.510. For any two-species laminates with fiber stress at proportional limit ratios between 0.908 and 0.510, the difference between actual and calculated values as shown may be used as a correction factor in moment calculations. Similar note must be made here as in a previous section, in that this correction factor (C) is for beams two inches in depth. For beams other than two inches in depth a correction factor (C′) as determined by Newlin and Trayer also must be applied (13).

Conclusions

1. The calculation of effective modulus of elasticity by the equation originally developed for plywood and adapted to two-species laminates does not accurately predict the stiffness of most two-species beams. A correction factor of 0.954 must be applied to the calculated stiffness to obtain values equal to test results.

2. The calculated fiber stress at proportional limit of two-species laminates obtained by the transformed moment of inertia method averages about 20 per cent greater than the test results. The correction factor (0.7975) is best used in the calculation of bending moment at fiber stress at proportional limit.

3. The calculated modulus of rupture of two-species laminates obtained by the transformed moment of inertia method does not accurately predict the strength of most two-species beams.

4. The difference between actual or test modulus of rupture and modulus of rupture calculated by the transformed moment of inertia method is a function of the ratio of face strength to core strength and also the ratio of core thickness to total depth of beam. Correction factors are presented which may be applied directly to the maximum bending moment calculation in design practice.

5. The form factors determined in this study are for two-species laminates with a depth of two inches. For beams of depth greater than two inches, they should be used in conjunction with the established form factors for beams more than two inches deep.

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Preliminary Report on a Proposed New Method of Estimating the Service Life of Exterior Grade Plywood[1]

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A project has been undertaken to test a proposed new method of estimating the service life of plywood based upon the rate of reduction in strength of a bond with time in service and the correlation between the rates of strength reduction produced by accelerated weathering and service exposure. The description does not include a discussion of the results as work has only recently been started, but is primarily restricted to a discussion of the project design, work completed and difficulties encountered.

Introduction

DURING THE SUMMER of 1954 the author worked as a student assistant at the Forest Products Laboratories of Canada on a research project entitled, "Rates of Reduction in the Strength of Phenolic Resin Bonds of Douglas-Fir Veneers Produced by Accelerated Weathering and Test Fence Exposures". This project has three purposes. The first is to arrive at a correlation between: (a) the rates of reduction in strength of weatherproof and non-weatherproof phenolic resin bonds of Douglas-fir plywood produced in days or weeks by means of accelerated weathering treatments and (b) the rates of reduction in strength induced by prolonged exposure to the natural elements. The second purpose is to demonstrate whether or not the rate of strength reduction induced by accelerated weathering treatments may be used to differentiate between those bonds that would be weatherproof and those that would not. The final purpose is to correlate estimates of bond strength based upon percentage wood failure with those based upon mechanical test values.

As the project is of long term design and work has only recently been started, a discussion of the results and their significance cannot be included in this paper. The remainder of this paper will therefore be restricted primarily to a discussion of the methods used, the progress of work to date, and the difficulties met.

Importance of Project

Natural weathering is a time-consuming process. If this time can be reduced from months and years to days and weeks by "accelerated weathering" treatments, an advantage is gained by both the glue manufacturer in evaluating new glues and by the consumer in selecting the best glue for his purpose. It is important to keep in mind that, in order to be of use, the results of an accelerated weathering treatment must correspond closely with the results of a known period of normal weathering.

Previous Investigations

Few plywood weathering studies have made use of mechanical tests. Most exposure studies (test fence) base their analysis of plywood durability upon the rate of glue-line delamination around the edge of test specimens. Correlations between exposure tests and accelerated weathering tests have been based upon the rate at which specimens have delaminated on the test fence compared to mechanical tests applied after the specimen has been subjected to only one accelerated weathering treatment. Of this method, Northcott (2)[2, 3] says: "This principle of predicting the service life of a glued bond from the results of tests conducted after a single weathering treatment appears to be fundamentally wrong."

The U. S. Forest Products Laboratory has exposed panels over a 15-year period. The glue-line quality after a chosen period of weathering was rated on the basis of "the percentage of joint area open and the percentage of wood failure." (4) Several types of accelerated weathering tests were available on which to correlate test fence weathering results. However, no record was made of the rate at which the glue lines lost strength in service.

In a weathering and mechanical test investigation carried out by the British Forest Products Laboratory (1), the investigators concluded that any indications of the mechanical test were nullified by the weakness of the wood (due to deterioration induced by weathering). The results of work carried out by the Vancouver Forest Products Laboratory (3) appeared to refute the deduction that weakness of wood nullified the indications of the mechanical test. A series of accelerated weathering tests when compared with the weathering tests of the British Forest Products Laboratory showed a very high correlation between the number of years of weathering and the logarithm of the number of boiling and drying (accelerated weathering) cycles which are required to produce identical percentage reductions in strength. In other words, the glue bond cannot be considered separate from the wood. Northcott (2) claimed that: "In the case of phenolic resin adhesives, it appears that the durability of the bond is definitely associated with the wood; with its chemical properties, its resistance to fatigue, and its resistance to decay."

The results of the above mentioned research project (3) showed that the strength of weatherproof bonds is reduced by repeated boiling and drying (and through inference by weathering), and that non-weatherproof bonds suffer much more rapid reduction in strength than do weatherproof bonds (see Fig. 1). A correlation of the percentage reduction of bond strength produced by a series of boiling and drying cycles with the reduction in

[1] Winning paper in undergraduate division, 1955 Wood and Wood Products Award, sponsored by Vance Publishing Co., Chicago. Award presented at FPRS Ninth National Meeting, June 21–24, 1955, in Seattle, Wash.

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[2] Numbers in parentheses refer to literature cited.

[3] P. L. Northcott, head of the plywood unit, Vancouver Laboratory, Forest Products Laboratories of Canada.

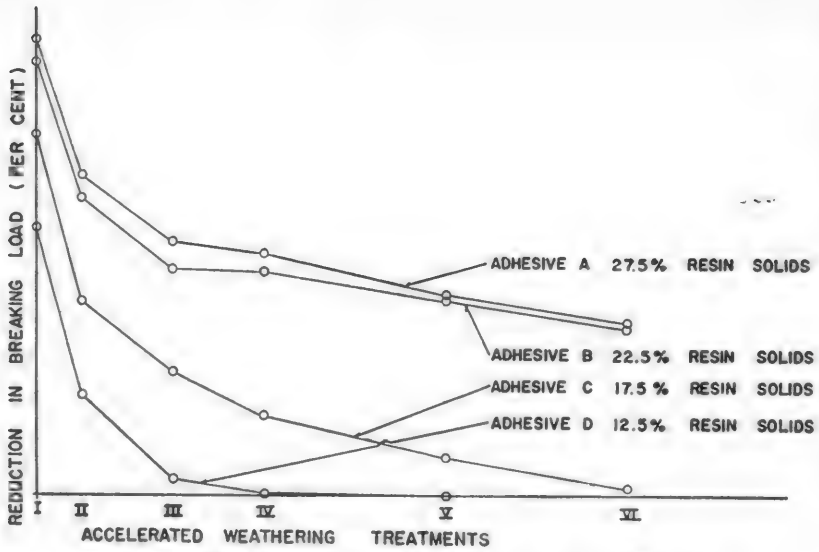
REDUCTION IN BREAKING LOAD (PER CENT)
ADHESIVE A 27.5% RESIN SOLIDS
ADHESIVE B 22.5% RESIN SOLIDS
ADHESIVE C 17.5 % RESIN SOLIDS
ADHESIVE D 12.5% RESIN SOLIDS
I II III IV V VI
ACCELERATED WEATHERING TREATMENTS

Fig. 1.—Relationship between bond strength, per cent resin solids, and severity of accelerated weathering treatments.

strength which results from various periods of normal weather exposure is a logical conclusion to the above principles.

Design of Project

For purposes of statistical analysis, the project was designed on a factorial system. In other words, each variable that might have had an effect on the results was listed as a factor.

The first factor was the three weathering systems. One system was a boiling and drying accelerated weathering treatment. The second system was a test fence exposure of panels protected with three coats of paint. The three coats of paint consisted of one coat of aluminum undercoat and two coats of exterior white paint. The third system was a test fence exposure of unprotected panels.

The second factor was the seven degrees of weathering severity followed by mechanical tests on the glue line to record the strength reduction induced by each. The glue lines were tested after the following accelerated weathering severities, each one designated by a number:

Severity one—The glue lines are tested dry, that is, with no weathering. Before testing, all specimens must be conditioned to an equilibrium moisture content in an atmosphere of 30 per cent relative humidity and a temperature of 70° F. in order to insure that all specimens will be tested with nearly the same moisture content.

Severity two—The glue lines are tested after four hours in boiling water and 20 hours of drying at 170° F. (i.e. after one accelerated weathering cycle) and subsequent reconditioning to equilibrium moisture content in the 30% relative humidity and 70° F. atmosphere.

Severity three—The glue lines are tested after two accelerated weathering cycles and subsequent reconditioning.

Severity four—The glue lines are tested after four accelerated weathering cycles and subsequent reconditioning.

Severity five—The glue lines are tested after six accelerated weathering cycles and subsequent reconditioning.

Severity six—The glue lines are tested after ten accelerated weathering cycles and subsequent reconditioning.

Severity seven—The glue lines are tested after 20 accelerated weathering cycles and subsequent reconditioning.

Similarly, the panels on the test fence will be tested after the following weathering periods, each one being designated by a number:

Severity one—The glue lines are tested dry. For this, the data from accelerated weathering severity one will be used.

Severity two—The glue lines are tested after six months' exposure.

Severity three—The glue lines are tested after one year's exposure.

Severity four—The glue lines are tested after three years' exposure.

Severity five—The glue lines are tested after six years' exposure.

Severity six—The glue lines are tested after ten years' exposure.

Severity seven—The glue lines are tested after 15 years' exposure.

Severity eight—The glue lines are tested after 20 years' exposure.

Again, the specimens will be subjected to the same conditioning before testing that the accelerated weathering specimens received, namely to equilibrium moisture content in an atmosphere of 30% relative humidity and 70° F.

The third factor was the use of four phenolic resin adhesive strengths. These range from "weaker-than-the-wood" to "stronger-than-the-wood". It is reasoned that a "weaker-than-the-wood" bond will break as a result of a failure of the bonding material while a "stronger-than-the-wood" bond will fail through the bonded wood. The four adhesive strengths are designated as glues A, B, C, and D, in order of strength. Glue A contains 26.5 per cent resin solids and is the same strength as one currently used in the manufacture of Douglas-fir Exterior Grade plywood. Glue B contains 22.5 per cent resin solids and is attained by extending the recipe for glue A with proportionate amounts of walnut shell flour, caustic soda, soda ash, water, mica, and stove oil to such an extent that the required percentage of resin solids is attained. Glues C and D contain 18.5 per cent and 12.5 per cent resin solids respectively and are attained by furthering the extension of glue A. The exact extension is calculated before mixing begins.

The fourth factor was the ten trees, each designated by a number from one to ten. Several trees, rather than one, were used to prevent a bias in the results due to characteristics of one particular tree.

The fifth factor is the two glue lines —the loose-to-loose and the tight-to-loose. This is considered a factor because the two glue lines differ in the nature of their joined surfaces. The differences can be explained thus. The natural shape of peeled veneer is cylindrical, the shape of the log. This natural shape is changed by the peeler knife blade which tends to flatten the veneer. Consequently, the inner surface of the veneer (the inner surface of the natural cylindrical shape) is brought under tension perpendicular to the grain in the direction in which the log is being peeled. This tensile force causes intermittent failure of the wood on the inner surface. Thus small checks, called lathe checks, appear on that surface. The outer surface, because it was not under a tensile pull, does not have lathe checks. The inner surface with the lathe checks is called the loose face of the veneer and the outer surface without the lathe checks is called the tight face of the veneer.

In plywood, the veneers are arranged so that tight faces are on the outside for reasons of quality of finished product. Consequently, the glue lines in a three-ply panel must be (a) a loose face bonded to a loose face and (b) a loose face bonded to a tight face. (See Fig. 2).

Procedure

Selection of Veneer: At the beginning of June, 1954, a Douglas-fir plywood plant in the Vancouver area selected ten Douglas-fir peeler logs of

the best quality, no two of which originated from the same tree, and allocated them for the use of the Vancouver Forest Products Laboratory. The logs were rotary-peeled into 1/10-inch veneers. From the heartwood veneer of each tree there were selected 20 4-ft. by 8-ft. veneer sheets, the remainder reverting back to mill use. The tight face of each sheet was clearly marked with its tree number. The veneers were then put through the veneer dryers at the regular heartwood schedule, recollected, and taken to the Forest Products Laboratory.

At the Laboratory, the groups of 20 veneers from each tree were sorted and the 12 best veneers were selected for use, the remainder being kept for reserve. Three veneers from each tree were assigned to be manufactured into a plywood panel using glue A. The same was done for Glues B, C, and D. Thus, at this stage, there was enough veneer selected and grouped to make 40 plywood panels, one for every combination of tree and glue.

The veneer that was to become the core was then cut into 12-inch by 48-inch core strips. The 12-inch width was the most suitable size for the glue spreader which was used in the plywood plant laboratory. The use of the 48-inch length was a minor mistake in that it did not allow for trimming of the finished plywood panel to the final 48-inch width. Consequently, most of the plywood panels were short about ½ inch of core veneer along one edge.

Manufacture of Plywood Panels: The ten plywood panels alloted to glue A were the first to be made. Glue A, containing 26.5 per cent resin solids, is the same as that used in regular production at the plywood plant. Glue A panels were made, at the same time, with regular production line glue, equipment, crews, and methods. In laying up the panels, care was taken to see that the two glue lines remained distinct one from the other and uniform in arrangement throughout their length, by placing the loose sides of the face veneers on the inside and the tight side of the core facing up.

The other three groups of panels, namely, glues B, C, and D, required a modification of the method used for glue A. The glues had to be mixed to the required percentage of resin solids and spread in the small glue-spreader in the plant laboratory, and the panels had to be pressed in the regular plant presses.

At this point, serious difficulty was encountered. Each extension of the glue required the addition of an increasing amount of water. This meant that the total amount of water present in a panel before pressing was also

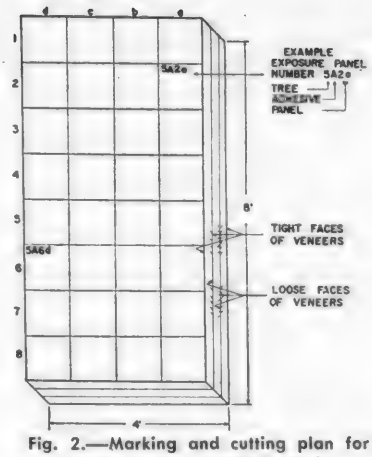

Fig. 2.—Marking and cutting plan for 1-foot square exposure panels.

increased. The result of this was first noticed in the glue B panels which had two small steam blisters; that is, the steam generated under pressure by the hotpress reacted upon release of pressure, to force the veneers apart and so break the uncured bond. Glue C, with an even greater amount of water, resulted in panels so blistered that they were not useable. It was then decided that more veneer would be selected from the reserve, the glue would be remixed and the new panels pressed 10 minutes instead of 4½ minutes as in the previous groups. This was done in the hope that it would allow the steam to dissipate harmlessly. Only moderate success resulted. There were several small blisters in the second group of glue C panels and glue D was severely blistered. All the plywood panels were then taken to the Vancouver Forest Products Laboratory.

Because there was not sufficient material in the glue C and D panels from which to cut the required number of foot-square exposure panels, it was decided to deviate sharply from the original plans by manufacturing the deficient number of exposure panels with laboratory equipment from stock selected from the reserve veneer. The procedure here was to make each exposure panel as a separate unit with 13-inch square face veneer and 6½-by 13-inch core veneer. The glue spreader and hot press in the Vancouver Laboratory were used for this purpose.

Marking of Plywood Panels: At this stage, each 4- by 8-ft. panel was marked into 32 1-ft. squares, making sure that all markings were placed so that the tight-to-loose glue-line was uppermost (see Fig. 2). It had been planned to allot from each panel, on a strictly random basis, one square to each of the 21 combinations of weathering systems and weathering severities. However, because of the numerous edges with short cores, areas of

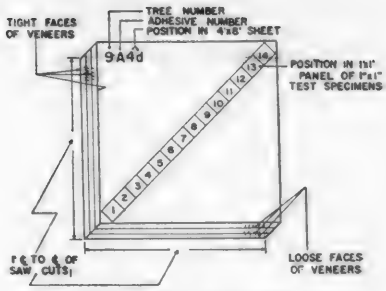

Fig. 3.—Marking and cutting plan for test specimens.

steam blisters, and shortage of squares within the panels in some cases, the random selection was modified so that these defects were eliminated and the panels manufactured in the laboratory were incorporated into the randomized allotment. Each exposure panel so selected was then marked with: a tree number from 1 to 10; a glue letter from A to D; and a panel code from 1a to 8d (see Fig. 2). The 4- by 8-ft. panels were then sawn into one-foot squares and the selected squares, totalling 840, were alloted equally according to the prearranged randomized pattern to the three weathering systems.

Data Cards: For purposes of recording and filing information, a data card for each weathering panel was printed. On each card were written all readings, measurements, and other pertinent information that was necessary.

Accelerated Weathering: The accelerated weathering treatment used in the project was a simple boiling and drying technique, using boiling tanks and forced-draft ovens with thermostatic control. As the time required for each severity was from zero (severity one) to twenty (severity seven) days, mechanical testing was done concurrently with accelerated weathering; i.e., testing was done soon after one severity was completed and while the next was being performed.

Upon completion of the boiling and drying treatment, each panel was brought to equilibrium moisture content (or to constant weight) in an atmosphere of 70° F. and 30 per cent relative humidity. The test specimens were cut from each panel and marked according to Fig. 3 and then placed in the humidity chambers for reconditioning to equilibrium moisture content. The humidity chambers are converted ice boxes containing trays filled with a saturated solution of calcium chloride, a circulating fan, and temperature control. An enclosed atmosphere at 70° F. surrounding such a solution has an equilibrium relative humidity of 30 per cent. In practice, the relative humidity ranged from 29 to 32 per cent.

Fig. 4.—Part of glueline cleavage machine.

Mechanical Testing on the Glueline Cleavage Machine: After reconditioning, the specimens were sawn from the exposure panels and tested mechanically to find the residual strength of each glue line. This was done on the glueline cleavage machine developed for this purpose at the Vancouver Laboratory. The machine consists of a hydraulic jack directly beneath a 90° knife edge (see Fig. 4). The specimen is placed on the head of the jack in such a position that when the jack is raised the knife-edge will be aligned directly along the glue line. The jack, powered by a small electric motor, is equipped with a pressure gauge calibrated to read the total force on the specimen. The test itself is completed by activating the jack so that the specimen is raised against the knife edge at a constant speed until a force is developed which is sufficient to cleave the specimen along the glue line. The magnitude of this force is recorded on the panel data cards. The specimens were tested in such a way as to eliminate the effect of consistently testing one glue line before the other; i.e., odd numbered specimens were tested on the tight-to-loose glue line first while even-numbered specimens were tested on the loose-to-loose glue line first.

Other Measurements and Calculations: Immediately before testing, the specimens were weighed and the three dimensions measured. Also, at this time, the per cent of summerwood bonded to summerwood was estimated for each glue line. After testing, the specimens were oven-dried, the oven-dry weight taken and oven-dry volumes measured with a mercury-displacement volume meter. The two weights and the volume were required in order that the moisture content at the time of testing and the specific gravity of the specimen could be calculated. It is thought that a correction factor can be applied to the breaking load to offset the effect of variations of these two factors. Similarly, a correction factor might be applied to correct for the effect on the breaking load of variations in the percentages of summerwood bonded to summerwood.

The per cent wood failure of each specimen has yet to be read. From this an attempt will be made to correlate estimates of glue-line strength based upon per cent wood failure with those based upon mechanical tests. This will give an indication of the reliability of per cent wood failure as an estimate of bond strength.

After all tests and measurements were made, the specimens were systematically filed for future reference and study.

Test Fence and Weathering Exposures: The weathering exposure panels were fastened on a 140-foot wire test fence with a southerly exposure. They were positioned high enough on the fence so that the undergrowth will not shade or otherwise protect the panels (see Fig. 5). One group was protected with a vapor barrier as previously described and the other was unprotected. These panels will be periodically removed from the test fence, examined, and the glue lines tested according to the weathering severities previously described.

Conclusions

Much work remains to be done on the project. Also, considerable time will elapse before the final results are tabulated. Only one-third (those receiving the accelerated weathering treatment) of the foot-square panels have been tested; the rest will be tested at increasing intervals over the next 20 years. It is planned to publish interim reports; the first about 1957.

It is expected that the final results will show (a) that the strength of "weatherproof" bonds is reduced by weathering just as it is reduced by repeated boiling and drying, and (b) that "non-weatherproof" bonds suffer a much more rapid reduction in strength than do weatherproof bonds. It is anticipated that the rates of reduction in strength caused by repeated boiling and drying can be used to predict the service life of plywood bonds with greater accuracy than has previously been possible.

Fig. 5.—Test fence with 1-foot square exposure panels.

Some difficulty was encountered in eliminating all extraneous variables and their effects on the results. The panels made with glues A and B were pressed for 4½ minutes while those made with glues C and D were pressed for 10 minutes. Also, half of the glue D panels were made in foot-square units rather than in 4-ft. by 8-ft. panels. Probably the effect of these discrepancies is negligible. However, they must be considered when interpreting the final results.

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Sorption Hysteresis in Relation to Wood Thickness[1]

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A study was made of the influence of wood thickness on sorption hysteresis. It was found that any influence of thickness is slight and the size of the wood specimen is not a major factor causing elimination of the hysteresis effect in sorption measurements. Under carefully controlled conditions, wood specimens of large sizes will still exhibit sorption hysteresis.

Introduction

WOOD AND OTHER CELLULOSIC materials, if exposed to normal atmospheric conditions, contain a certain amount of moisture the magnitude of which will vary with changes in atmospheric conditions. These changes in moisture content are of great importance since they, in turn, cause a change in most of the physical and mechanical properties of these materials. The sorption of water vapor by cellulosic materials has therefore been studied extensively (5).

When wood is exposed to a constant relative humidity and temperature, it will eventually reach a moisture content which is in equilibrium with these conditions. If moisture content is plotted as a function of relative humidity at constant temperature, the resulting sorption curve for wood as for all cellulosic materials is characteristically S-shaped. It has been found that, for a given relative humidity, the equilibrium moisture content is higher when equilibrium is approached by desorption than when it is approached by adsorption. This phenomena is known as sorption hysteresis. Fig. 1 shows a typical hysteresis loop for white spruce, formed by a desorption curve which lies higher than the adsorption curve (8).

Seborg (2) showed that the hysteresis ratio obtained by dividing the adsorption by the desorption moisture content is almost a constant over most of the range of relative humidities. Stamm and Woodruff (7), working with white spruce wood, obtained hysteresis ratios varying from 0.79 at 10 per cent relative humidity to 0.88 at 95 per cent relative humidity with an average of 0.83. At 0 per cent and at 100 per cent, the hysteresis ratio is unity if the measurements are made on cycles other than the first. Material which has never been dried will show a higher original desorption curve (3), but after drying and resaturating, the hysteresis loop will become reproducible.

In the light of the foregoing, it might appear that a marked hysteresis effect operates to the advantage of the wood user. On the basis of the hysteresis loop, comparatively large changes in atmospheric humidity conditions would, within limits, cause little or no changes in moisture content. Urquart and Eckersall (9), however, have shown that the area bounded by the hysteresis loop represents an area of equilibrium. Equilibrium moisture content may occur at any point in this area, depending on the preliminary and conditioning treatments of the specimen. The maximum hysteresis effect is only obtained when working under very carefully controlled conditions. Oscillating relative humidity conditions, where alternating adsorption and desorption are allowed to occur, will result in a desorption curve which falls within the general hysteresis loop (Fig. 1).

Stamm and Loughborough (6) have shown that hysteresis is essentially eliminated when working with large specimens, even under quite carefully controlled conditions. This they explained as being due to a moisture gradient being set up in the wood specimen, which, in turn, causes alternating adsorption and desorption within the specimen.

Sergovskii (4), on the other hand, has shown that hysteresis increases with an increase in specimen size up to pieces 8 millimeters thick and 50 millimeters long, after which it remains fairly constant. It therefore appears that the size of a wood specimen would have an influence on the equilibrium moisture content percentages obtained in sorption measurements. The following study was designed to investigate the extent of this influence.

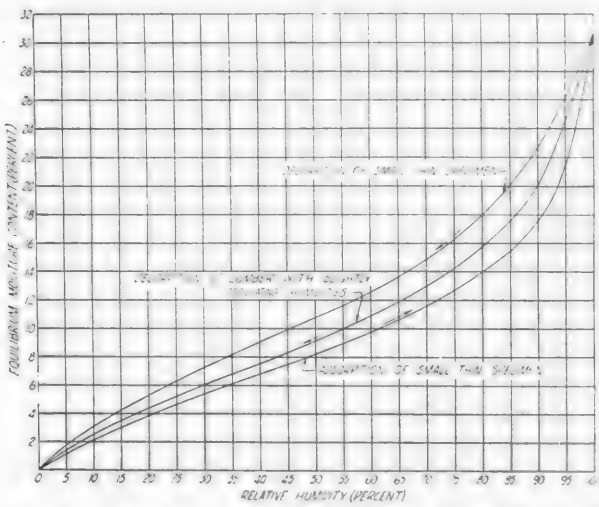

Fig. 1.—Typical hysteresis loop for white spruce. (From ANC Bull. 21, Kiln Certification (8))

[1] Entered in the Graduate Division, 1955 Wood and Wood Products Award, sponsored by Vance Publishing Co., Chicago.

[2] Condensation of a thesis submitted in partial fulfillment of the requirements for Master of Wood Technology degree, School of Natural Resources, University of Michigan, Ann Arbor.

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Fig. 2.—View of experimental apparatus.

Purpose and General Design of Experiment

As has been indicated above, there is evidence that the size of a wood specimen is a factor which, due to the occurrence of alternating adsorption and desorption within a large piece of wood during the drying process, has the same effect on sorption hysteresis as relative humidity oscillations outside the piece. That hysteresis is eliminated in large wood specimens has been universally accepted, but the minimum dimension at which hysteresis is eliminated and the general relationship between thickness of wood and the size of the hysteresis loop as expressed by the hysteresis ratio has never been investigated. This study was designed to determine the influence of wood thickness on sorption hysteresis under carefully controlled relative humidity conditions.

Specimens of five different thicknesses having constant length and width comprised the basic variant. Rather than taking one set of specimens through one complete sorption cycle from green to oven dry and back, the problem was approached statistically. Six different constant relative humidity conditions distributed over the range from zero to 100 per cent relative humidity were selected. Two groups of specimens of varying thickness were brought into equilibrium with each of these relative humidity conditions, one by desorption from the green condition and the other by adsorption from the oven-dry condition. This was expected to give six points each on the desorption and on the adsorption curves. By plotting the moisture content at any given relative humidity separately for each thickness, it was anticipated that a family of curves might be obtained, where the thinnest specimens would show maximum hysteresis, the thickest specimens minimum or no hysteresis, and the curves for specimens of intermediate thickness would fall between the two according to the influence of thickness.

Table 1.—SUMMARY OF VARIABLES AND NUMBER OF SPECIMENS USED

Variable	Intervals	No. of classes in variable
Thickness (inch)	0.8, 0.4, 0.2, 0.1, 0.05	5
Relative humidity (per cent)	19, 31, 57, 71, 83, 89	6
Type of sorption	desorption and adsorption	2
	No. of variable combinations:	60
	Replications:	3
	Total No. of Specimens:	180

Table 2.—SATURATED SALT SOLUTIONS USED TO MAINTAIN CONSTANT RELATIVE HUMIDITY CONDITIONS

Salt	Relative humidity at 75° F. Percent,
Potassium acetate ($KC_2H_3O_2$)	19
Calcium chloride ($CaCl_2 \cdot 6H_2O$)	31
Sodium bromide ($NaBr \cdot 2H_2O$)	57
Potassium nitrate and ammonium chloride mixture ($KNO_3 + NH_4Cl$)	71
Potassium bromide (KBr)	83
Zinc sulfate ($ZnSO_4 \cdot 7H_2O$)	89

In effect, the study was a factorial design with three variables: thickness, relative humidity, and type of sorption (desorption or adsorption), with three replications (samples). This design lent itself readily to an analysis of variance (See Table 1).

Experimental Procedure

Three trees of large-tooth aspen (*Populus grandidentata* Michx.) were cut specifically for this study in order to insure a knowledge of the prehistory of the material. Care was taken at all times after the trees had been cut to keep the wood from drying prior to the experimentation. All specimens were machined in the green condition to 3 inches in length, 2 inches in width, and five different thicknesses (Table 1) with an accuracy of ± 0.005 inch. By a random process, each was identified as either a desorption or an adsorption specimen and was assigned to one of the six relative humidity conditions (Table 1).

The desorption specimens were carefully kept in a saturated condition, whereas the adsorption specimens were dried gradually to about 6 per cent moisture content at room temperature by consecutive exposure to humidity rooms controlled to 80, 50, and 30 per cent relative humidity. They were then oven dried to constant weight at 212° F. All specimens were end coated with a rubber-base compound to minimize moisture movement through the end grain. The weight of the end coating was determined as carefully as possible, in order to account for it in the calculation of the moisture content percentages.

The various relative humidity conditions were maintained in a closed system by the use of saturated salt solutions with an excess of solid phase. (Table 2).

The apparatus consisted of six desiccators. Three of these had a provision for air agitation in the form of a small propeller, which was connected to an air motor above the desiccator through a mercury vapor seal. The salt solutions were contained in the lower part of the desiccator, with the specimens standing on a perforated plate above (Fig. 2). Those desiccators

which had a provision for air agitation were used for the desorption measurements. Circulation was considered much more important for the desorption specimens which had initial moisture content values as high as 200 per cent.

The table on which the apparatus was standing was vibrated sufficiently by the motors to cause a perceptible agitation of the salt solutions. This insured constant relative humidity conditions in the desiccators. The room in which the experiment was conducted was controlled to 75 ± 1.5° F., which caused a maximum calculated relative humidity variation of 0.3 to 0.4 per cent within the desiccators, depending on the particular solution in question.

The desorption and adsorption specimens in saturated and oven-dry conditions respectively were introduced into separate desiccators, controlled to the various humidity percentages. Exceptions to this were the specimens assigned to relative humidity conditions of 31 and 57 per cent, both of which groups had been brought to equilibrium in a humidity room at 80° F. and 79 per cent relative humidity, controlled to ± 2 per cent. There, the specimens reached an average equilibrium moisture content of 15.4 per cent (identical averages were reached by both groups of 15 specimens) and were introduced into their respective desiccators at that moisture content. All specimens were left in the desiccators until they had reached equilibrium.

The desiccators were kept closed at all times, except for sample weighings to determine whether the specimens had reached equilibrium. In order to minimize the disturbing effect on the relative humidity conditions which would be caused by opening the desiccators, only the three thickest specimens were weighed during the run of the experiment.

It was assumed that the thickest specimens would be the last ones to reach equilibrium. After the thickest material had reached constant weight, the equilibrium weight for all specimens was determined. All specimens were then dried to constant weight at 212° F. and the oven-dry weights were determined.

All weighings were made either on a torsion balance or an analytical balance, depending on the specimen size, which made it possible to determine the moisture content to 0.1 per cent. A petri dish was used for all weighings on the analytical balance in order to minimize moisture loss or gain from the surface of the specimen. Due to a limited amount of equipment, the experiment had to be carried out in two shifts. This, however, was not considered to have any influence on the results.

After the experiment had been completed, the relative humidity over the specific salt solutions which were used in the experiment was checked with a Bendix–Friez hygrothermograph. The potassium acetate solution, which according to the literature should have maintained a relative humidity of 19 per cent, gave repeated readings of 23 per cent. The relative humidity of the potassium acetate solutions, calculated from direct measurements of vapor pressure made under vacuum with an oil manometer, was 24 per cent. Since the latter method is more accurate, the relative humidity over the potassium acetate solution was therefore taken to be 24 rather than 19 per cent.

Results and Discussion

The time needed for any one group of specimens, exposed to the same combination of relative humidity and type of sorption, to come into equilibrium exceeded two and one-half months. It is interesting to note that the initial desorption or adsorption proceeded very rapidly, but as equilibrium was approached, the rate of sorption was extremely slow regardless whether it was desorption or adsorption. The use of the fans also seemed to have no appreciable effect on the rate of sorption in the final stages. The results are shown in Table 3.

It is at once evident from Table 3 that there is a definite hysteresis effect for each relative humidity condition regardless of the thickness of the specimens. There are, however, certain trends for the moisture content to increase or decrease with an increase in thickness, but these trends are not uniform for all cases and cannot be explained on the basis of any one factor alone. Only the desorption specimens in equilibrium with 24 per cent relative humidity show the expected trend of a reduction of the hysteresis effect accompanying an increase in thickness. The adsorption specimens in equilibrium with relative humidity conditions of 31 and 57 per cent, and the desorption specimens in equilibrium with those of 57 and 83 per cent show a definite trend in moisture content such as might be expected if true equilibrium had not been attained. In all the remaining groups of specimens, any trends accompanying an increase in thickness are either non-existent or not very clearly defined.

A separate analysis of variance was made for each group of specimens consisting of five thicknesses and three replications, or a total of 15 specimens, with the relative humidity and the type of sorption constant. There were 12 such groups, and thickness proved to be significant for all groups except the desorption specimens in equilibrium with relative humidity

Table 3.—EQUILIBRIUM MOISTURE CONTENT PERCENTAGES FOR DESORPTION AND ADSORPTION SPECIMENS OF FIVE DIFFERENT THICKNESSES AT CONSTANT RELATIVE HUMIDITY CONDITIONS AND 75° F.

Thickness (inch)	Relative Humidity (Per Cent)											
	24		31		57		71		83		89	
	1*	2†	1	2	1	2	1	2	1	2	1	2
0.05	3.9	6.9	4.9	6.6	8.9	10.9	11.1	14.7	13.4	18.3	16.7	22.4
	3.9	6.7	4.9	6.8	8.9	10.9	11.1	14.6	13.5	18.1	16.8	22.0
	3.8	6.9	4.9	6.7	8.9	11.2	11.2	14.8	13.3	18.1	16.9	22.2
0.10	4.0	6.1	4.8	6.3	8.8	10.9	11.3	14.9	13.3	18.5	17.0	22.3
	4.0	6.4	4.9	6.8	8.9	11.6	11.3	14.8	13.2	18.4	17.2	22.3
	4.0	6.4	4.7	6.4	8.8	11.0	11.2	14.6	13.1	18.7	17.2	21.7
0.20	3.8	6.2	4.5	6.7	8.7	11.3	11.3	14.5	13.2	18.9	17.1	22.4
	4.0	6.1	4.7	6.7	8.8	11.7	11.2	14.5	13.3	18.8	17.2	22.3
	3.9	6.1	4.7	7.0	8.6	11.7	11.1	14.6	13.1	19.1	17.3	22.2
0.40	3.9	5.9	4.3	6.9	8.2	11.6	11.1	14.4	12.9	18.7	17.0	22.4
	3.8	6.0	4.4	6.8	8.3	11.7	11.2	14.4	12.9	18.8	17.4	22.5
	3.9	6.0	4.4	6.7	8.4	11.8	11.3	14.4	12.8	18.9	17.0	22.7
0.80	3.8	5.9	4.2	6.8	8.2	11.8	10.9	14.9	13.2	19.1	16.8	22.6
	3.6	6.0	4.3	6.6	8.2	11.5	10.8	15.0	13.2	18.8	16.9	22.4
	3.7	5.9	4.2	6.4	8.3	11.8	10.5	14.9	13.2	19.2	16.7	22.5

* adsorption moisture content percentages.
† desorption moisture content percentages.

Table 4.—ANALYSIS OF VARIANCE, SHOWING F-RATIOS OF TESTS AGAINST EXPERIMENTAL ERROR

Source	Degrees of freedom	Mean square	F	$F_{.95}(x, y)$
Relative humidity conditions	5	999.36	53 537.20	2.29
Type of sorption	1	587.89	31 494.07	3.92
Thickness	4	0.0889	4.76	2.45
Relative humidty x sorption	5	16.50	884.02	2.29
Relative humidity x thickness	20	0.1205	6.45	1.66
Sorption x thickness	4	0.5458	29.24	2.45
Relative humidity x sorption x thickness	20	0.2103	11.27	1.66
Experimental error	120	0.0187	1.00	
Total	179			

Table 5.—ANALYSIS OF VARIANCE, SHOWING F-RATIOS OF TESTS AGAINST THE SECOND ORDER INTERACTION

Source	Degrees of freedom	Mean square	F	$F_{.95}(x, y)$
Relative humidity conditions	5	999.36	4 751.07	2.71
Type of sorption	1	587.89	2 794.89	4.35
Thickness	4	0.0889	0.42	2.87
Relative humidity x sorption	5	16.50	78.45	2.71
Relative humidity x thickness	20	0.1205	0.57	2.12
Sorption x thickness	4	0.5458	2.59	2.87
Relative humidity x sorption x thickness	20	0.2103	1.00	
Experimental error	120	0.0187		
Total	179			

Table 6.—ANALYSIS OF VARIANCE AFTER REDUCTION OF THE DESIGN BY TREATING THICKNESS AS REPLICATIONS

Source	Degrees of freedom	Mean square	F	$F_{.95}(x, y)$
Relative humidity conditions	5	999.36	5 239.88	2.41
Type of sorption	1	587.89	3 082 44	4.04
Relative humidity x sorption	5	16.50	86.52	2.41
Experimental error	48	0.19	1.00	
Total	59			

conditions of 31 and 89 per cent. In the absence of a unidirectional trend, however, this fails to be meaningful.

Drying curves showing the relationship between time and moisture content for the specimens 0.8 inch in thickness, which were constructed from the sampling data, established beyond any reasonable doubt that the specimens were definitively in equilibrium, i.e. any differences due to lack of equilibrium would be well within the limits of experimental error.

Analyses of variance were made for the experiment as a whole, and the essential figures are shown in Tables 4, 5, and 6. Table 4 shows the F-ratios obtained by comparison with the overall experimental error.

On that basis, all the variables as well as all the interaction terms are significant on the 5 per cent level. The fact that the mean square terms for thickness and all the interaction terms involving thickness are on the same general order of magnitude suggests that there might be several factors present which depend on thickness but do not exert their influence in the same direction.

Table 5 shows the F-ratios obtained by comparison with the second order interaction. Now, only relative humidity, type of sorption, and the interaction between relative humidity and type of sorption are significant.

Based on the assumption that thickness influences experimental error more than anything else, a separate analysis of variance was made using thickness as replications, which gives a factorial design with two variables and five replications. The essential figures are shown in Table 6.

The significant F-ratios of the second analysis of variance (Table 6) show clearly that there is an influence of relative humidity, type of sorption, and an interaction of relative humidity and type of sorption which is exerted beyond any influence which thickness might have. In the case of relative humidity, this is no more than one would expect. It is important, however, that the type of sorption is significant beyond the influence of thickness. Since type of sorption in this case is an expression for hysteresis modified for statistical treatment, it means that hysteresis does occur regardless of the thickness of the specimen. The significance of the interaction term is also no more than one would expect, since for a constant hysteresis ratio, the numerical difference between desorption and adsorption moisture content will be greater at the higher relative humidity conditions. Tabulations were made of the deviations from the grand mean of the means for each relative humidity-type of sorption combination after the effects due to relative humidity and type of sorption alone had been taken out. The resulting deviates formed a definite pattern, which indicates that a true interaction exists.

Table 7.—AVERAGE MOISTURE CONTENT PERCENTAGES AND HYSTERESIS RATIOS AT VARIOUS RELATIVE HUMIDITY CONDITIONS AND 75° F.

Relative humidity (per cent)	Adsorption moisture content (per cent)	Desorption moisture content (per cent)	Hysteresis ratio*
24	3.9	6.2	0.62
31	4.6	6.7	0.69
57	8.6	11.4	0.75
71	11.1	14.7	0.76
83	13.2	18.7	0.70
89	17.0	22.3	0.76

*Ratio of adsorption to desorption moisture content.

Table 7 shows the means for each combination of relative humidity and type of sorption, based on the moisture content values of 15 specimens, and the hysteresis ratios for each relative humidity. The magnitude of the hysteresis ratios indicates a large hysteresis effect. The values shown are not directly comparable with those of Seborg (2), since the former are computed on the basis of desorption data of material which had never been dried, and the latter are computed on the basis of sorption cycles other than the first. This largely explains the difference in magnitude of the respective hysteresis ratios. The hysteresis loop shown in Fig. 3 has been constructed from the data in Table 7. Inspection of the sorption curves shows that if the relative humidity of the potassium acetate solutions had been plotted at 19 rather than 24 per cent, the resulting sorption curves would have been of a rather unlikely shape. The desorption specimens which were brought into equilibrium with 31 and 57 per cent relative humidity conditions had previously reached an equilibrium moisture content of 15.4 per cent at 80° F. and 79 ± 2 per cent relative humidity. These conditions can be considered oscillating, and if the moisture content is adjusted to 15.7 per cent due to the temperature difference (6), it falls within the hysteresis loop as shown in Fig. 3. There can be no question that the specimens on the subsequent desorption crossed back to what can be considered the original desorption curve.

Differences in sorption of the various thickness levels, which were established by the statistical analysis, were not clearly explained by the experiment. Investigation showed that no correlation existed between sorption differences and the trees and position within the tree from which the specimens were taken. Although the influence of experimental error is be-

lieved to be minor, certain sources of uncontrolled variation could conceivably have been additive to cause differences in thickness classes. These are as follows:

1. The amount of end coating varied with the thickness of the specimen. Any errors caused by the use of the end coating might therefore vary with thickness. It was calculated on the basis of available data that the error due to solvent retention and oxidation of the end coating during oven drying could cause an aggregate error of 0.3 per cent in moisture content.

2. The ratio of surface area to weight varied with the thickness of the specimen. Any errors due to rapid initial loss or gain of moisture during weighings might therefore vary with thickness. The maximum error due to that source has been calculated to be 0.2 per cent moisture content on the basis of reweighings.

3. The length of time to reach equilibrium would vary with thickness. As it was indicated previously, lack of equilibrium was not a major factor, but might conceivably have caused a maximum error of 0.2 per cent moisture content.

Addition of the errors outlined above gives a maximum error of 0.7 per cent moisture content which might be attributed to differences in thickness. Since the maximum range of moisture content percentages for any one of the 12 groups of 15 specimens was 1.1 per cent, and the maximum difference between the averages for three samples of the same thickness within any one group was 0.9 per cent moisture content, it is indicated that the sorption differences between thickness classes are due to a combination of extraneous factors which are related to the size of the specimen.

Conclusions

The sensitivity of the present study was not sufficient to establish the exact influence of thickness of wood on sorption hysteresis. It may be that hysteresis decreases slightly with an increase in specimen size as indicated by Stamm and Loughborough (6), or it may increase with an increase in specimen size as shown by Sergovskii (4). The results of this study definitely show that whatever influence thickness may have is very slight. The elimination of the hysteresis effect in measurements made by Stamm and Loughborough (6) must therefore have been due to oscillations in relative humidity conditions alone, and not to the size of the specimen. This is supported by recent findings of Stamm,[3] which point out that the relative humidity fluctuations in his and Loughborough's study could have been of the order of 3 per cent between times of admission of steam to the humidity cabinet and times just prior to admission. This is indicated by recent electric hygrometer readings in chambers controlled with similar control equipment. Their fluctuations in relative humidity were therefore about 10 times those of the present study.

The size of the largest specimens used in this study, 0.8 x 2 x 3 inches, was certainly sufficient to result in the establishment of a moisture gradient, which indicates that the adsorption and the desorption mechanism must proceed in a uniform and unidirectional manner and that the presence of such a gradient does not cause appreciable alternating adsorption and desorption within the specimen. Therefore the size of a wood specimen would not be a major factor causing elimination of the hysteresis effect in sorption measurements. Under carefully controlled conditions, wood specimens of large sizes will still exhibit sorption hysteresis.

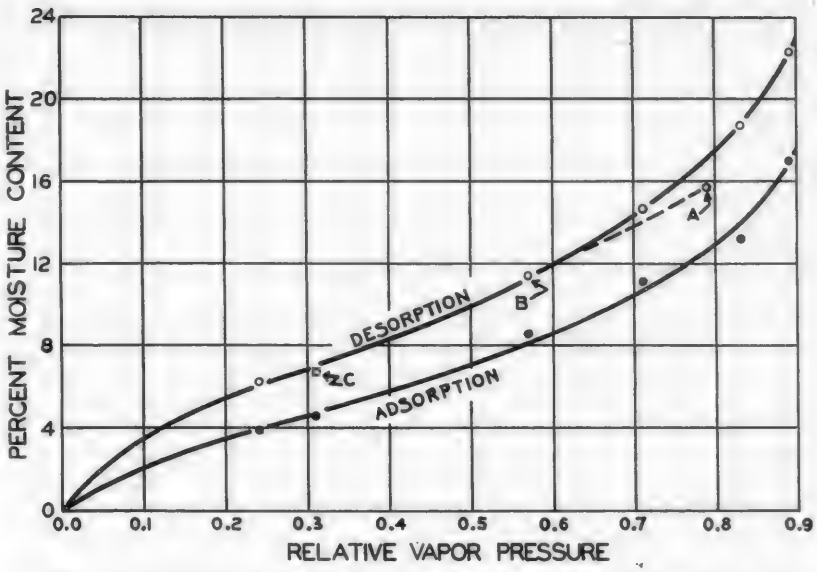

Fig. 3.—Adsorption and desorption curves and hysteresis loop of the experiment. (a)—intermediate equilibrium value for the groups reaching final values at (b) and (c). The dotted line indicates the probable path from (a) to (b) and (c).

[3] The information in the remainder of the paragraph was received from Dr. Stamm in a private communication.

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Variation in Taxifolin Content of a Douglas-Fir Stem Exhibiting Target Ring[1, 2]

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A quantitative examination of taxifolin concentration across a "target ring" specimen of Douglas-fir has shown that areas of included sapwood are deficient in this important extractive constituent. It would appear that Douglas-fir containing large amounts of "included sapwood" might exhibit unusual sulphite pulping properties. Under conditions favoring decay, the "included sapwood" zones would offer little resistance to the entrance of wood-deteriorating fungi.

Introduction

STEMS OF DOUGLAS-FIR *(Pseudotsuga menziesii* (Mirb.) Franco) grown in the interior region of the Pacific Northwest often display a "target ring" pattern when viewed on cross-section. The characteristic pattern is represented by three to ten alternately light- and dark-colored, concentric, circular areas (Fig. 1a). Pale-colored areas of variable width are interspersed among the zones of normal, darker-colored heartwood. Delineation appears to be associated with growth increments for the most part. Lighter-colored areas have the macroscopic appearance of normal sapwood, and so have been termed areas of "included sapwood" (3)[3]. It is probable that these are not zones of physiologically active sapwood. The reasons for development of this phenomenon in the living tree are not understood.

Normal heartwood of Douglas-fir contains higher amounts of extractives than corresponding sapwood. The heartwood may therefore be considered as that darker-colored wood of high extractive content which comprises the inner core of a stem. In contrast, the sapwood may be thought of as the pale-colored wood of low extractive content which occupies the peripheral position in a stem. The distinction within this species is further complicated by a broad sapwood-heartwood transition zone. The inclusion of light-colored bands within the heartwood area presents a discrepancy that can be examined in part through comparison of extracts from the different zones.

Taxifolin (dihydroquercetin) is a phenolic extractive of major importance in Douglas-fir. This flavonone type compound has been shown to function as a fungicide, and is thought to be largely responsible for the moderate decay resistance of Douglas-fir (6). The compound also inhibits the pulping of heartwood from this species by the normal sulfite process (5). In view of the importance of this single extractive, it was of interest to determine its distribution with radial position in Douglas-fir stems showing a "target ring" pattern. Although taxifolin is colorless, it was felt that areas of "included sapwood" might be indicative of an abnormal extractive balance involving this compound, as well as other darker-colored extractives (i.e. phlobaphenes, phlobatannins, and resin acids). Some evidence suggesting a variation in taxifolin content associated with these light-colored areas is provided by Fig. 2. The butt end of this log showed advanced decay in light-colored zones but none was perceptible in adjacent normal heartwood.

It has been reported for certain other species that the amount of extractives across a stem varies with radial position (1, 4, 9, 10). In most cases, the outer heartwood has been found to have the largest amount of extractives, while heartwood surrounding the pith contained the least. No conclusive data are available for Douglas-fir in this regard.

Method

A cross-sectional disc of "target ring" Douglas-fir measuring 15 inches in diameter was selected for study (Fig. 1a). Several samples of this type of material were collected at Quesnel, B. C. The ten alternating zones of light- and dark-colored wood were sampled by drilling several holes in each and carefully collecting the borings. The borings were reduced to 40-mesh wood meal in a Laboratory Wiley mill. These samples were dried for five days to establish equilibrium moisture content. A small quantity of each sample was weighed and oven-dried for purposes of moisture content corrections.

Approximately four grams of air-dried wood meal from each zone was put into tared paper extraction thimbles and weighed. The samples were then extracted on Soxhlets with methanol for 24 hours. The resulting alcoholic extracts were concentrated under reduced pressure to approximately 35 ml., and then diluted to exactly 50 ml. The amount of taxifolin in these extracts was estimated approximately by the method of Barton and Gardner (2), which is based on the reduction of taxifolin to eriodictyol. In the course of this reduction, a side reaction produces a lavender color which is reportedly specific for the 3-hydroxy flavonones such as taxifolin (7, 8). The intensity of the color indicates the amount of taxifolin present. Results of readings taken on a Fisher electrophotometer (blue filter 425-B) were compared with values of standard solutions obtained by Barton and Gardner. Per cent concentration of taxifolin in the samples was determined by dividing the experimental result in grams by the weight of the individual samples (corrected to oven-dry weight).

Results and Discussion

The results of this investigation are presented graphically in Fig. 1b. The true (peripheral) sapwood was found to contain the least amount of taxifolin, whereas all heartwood regions had higher concentrations. The in-

[1] A contributed paper.
[2] Research paper No. 11, Faculty of Forestry, University of British Columbia, Vancouver, B. C.
[3] Numbers in parentheses refer to literature cited.

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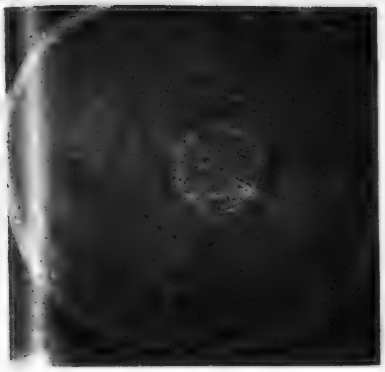

Fig. 2.—Advanced decay associated with areas of "included sapwood" in a "target ring" Douglas-fir stem.

cluded light-colored zones of the heartwood contained much smaller percentages of taxifolin than contiguous normally colored heartwood areas.

The distribution of taxifolin in the normal heartwood followed the pattern of extractives reported for other species, i.e. concentration increased with radial distance from the pith. It is interesting to note that included light-colored zones did not show this pattern. These areas appeared to represent a more constant level of taxifolin across the stem.

These results corroborate a previous study by the authors with less elaborate methods adapted from a reaction reported by Pew (7, 8).

On the basis of these studies, it would appear that Douglas-fir containing large amounts of "included sapwood" might exhibit unusual sulphite pulping properties. Under conditions favoring decay, the "included sapwood" zones would be similar to the true sapwood in as much as they would offer little resistance to the entrance of wood-deteriorating fungi.

Fig. 1a.—Cross-section of Douglas-fir stem showing "target ring".

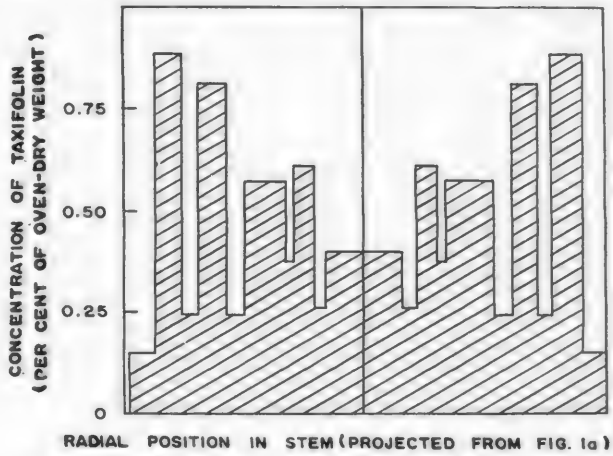

Fig. 1b.—Variation of taxifolin concentration with radial position in the "target ring" cross-section.

Acknowledgments

The authors wish to acknowledge facilities made available at the Vancouver Branch, Forest Products Laboratories of Canada. Special thanks are due Dr. J. A. F. Gardner, Head, Wood Chemistry Section, and members of his staff.

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Progress Report on Survey of Bending Strength Values of Dimension Lumber Used in Farm Work Buildings in the Northeastern States[1]

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A study was conducted in the Northeast to determine the range of strength values of local ungraded lumber used in farm work building construction. Also investigated was the practicability of developing simple rules to raise strength values of this class of dimension material or to insure specific minimum performance.

THE USE OF STRESS-GRADED LUMBER and the application of working stresses in urban construction is commonplace. Wherever building codes are in effect their use is mandatory. Farm buildings, on the other hand, are not subject to building code regulations and large amounts of local ungraded lumber is used in their construction. This use of local material is highly desirable. The problem confronting agricultural engineers is "How strong is this run of the mill material and what can be done to insure the safe use of such material in farm work-building construction?" The U. S. Forest Products Laboratory, Madison, Wis. and the Northeastern Forest Experiment Station are cooperating with the Agricultural Research Service, Beltsville, Md., in a study that should give the answer to these questions.

The best approach to this nationwide field is on a regional basis. This study, therefore, is intended to cover the New England States, New York, and Pennsylvania. A large share of the farm framing lumber used in this region is produced by small local mills and sold directly to the user without passing through customary marketing channels. This material is largely ungraded, with only the obviously unsuitable pieces culled out. Specifically, the objectives of this study are: (1) to determine how wide a range of strength values this ungraded material represents, and (2) the practicability of developing simple rules that would either (a) raise strength values of this class of dimension material or (b) insure specific minimum performance.

Approach to the Problem

Safe working stresses cannot be assigned to any piece of lumber unless it has been selected for strength. In any log-run lot of lumber, some pieces will have high strength and some low. From any log-run lot of material, perhaps but a small percentage would qualify for the highest structural grades.

Designs and required working stresses for lumber used in urban construction governed by building codes assume that each member shall carry its own full load with no help from adjacent pieces in case of failure. Such strict limitations are necessary because of the use to which such buildings are put, plus the fact that most of their framing members are enclosed and failures cannot be easily detected.

The conditions in the construction and use of farm buildings make possible a different approach to their design than is required for most urban construction. Farm barns or storage buildings are generally for private use where public liability is not involved. Framing members of barns are likely to be exposed so that the owner can detect trouble and make repairs before serious failure occurs. Because joists and studs are usually closely spaced, this means that if failure occurs in one, the load can be carried by adjacent members until repair or replacement is made. All of these conditions indicate that failure of individual pieces can be tolerated to a greater extent in farm than in urban buildings and that ungraded or partly graded framing lumber has a proper place here.

The safe use of nonstress-graded lumber in framing farm buildings does, however, require knowledge of the range of strength values in the material used. In this study, information was collected on bending strength values. Our analysis of that information will be in terms of working stresses suitable for farm building design.

The apparently obvious way to study strength values in any given lot of lumber would be to make machine strength tests of a large number of pieces from that lot. This procedure, however, is costly and time consuming. A different approach was used in this study. We already know the strength reducing effects of all the factors affecting the strength of lumber.[2] We also know that their effects on strength are about the same for all species. Therefore, from visual inspection of a piece of lumber in the field, we can estimate how much of its basic strength has been reduced by whatever knots or other strength-reducing features are present in the piece. A so-called "strength ratio" can then be assigned to it. This is the ratio of its actual strength to the average clear-wood strength of the species. In this way we are able to establish the range of strength ratios for any lot of dimension lumber at a nominal cost. Since the clear wood strength values in the various species is already known from standard strength tests, application of the range of strength ratios gives a fair estimate of the actual strength value in the lot of lumber surveyed, as well as information on the individual pieces.

[1] Presented at meeting of Northeast Section, FPRS, April 28–29, 1955, in Glens Falls, N. Y.

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[2] American Society for Testing Materials. 1949. Tentative methods for establishing structural grades of lumber. American Society for Testing Materials. Standard D245–49T.

Factors Influencing Strength

Before discussing further the progress of this study, a brief summary of strength factors is in order. Although there are actually many factors affecting the strength of lumber, a relatively few are of major importance. These are

Knots: Knots influence the strength of a piece of lumber according to size, number, and position in the piece. The character of the knot (loose or tight, sound or rotten) has little effect since effect on strength is due mainly to distorted grain around the knot. The effect of size is proportional to the width of the face in which the knot appears; i.e., the effect for a given size knot is greatest on a small width; least on a wide one.

Slope of grain: Slope of grain is a serious factor in weakening lumber and it can easily be and often is overlooked. Its effect on strength increases as the angle of slope increases. Diagonal grain can easily be detected on the radial surface of a piece of lumber; spiral grain usually is best observed on the tangential surface. Distorted grain associated with knots is taken into account in knot evaluation and should not be confused with slope of grain.

Offsize: A large share of the lumber used by farmers is manufactured at small sawmills. Many of these mills are poorly maintained and operated so that offsize lumber is common. We, therefore, have to consider this factor. Where bending strength is considered, offsize in width of a joist or rafter will affect its strength considerably, either way. **Wane** is in the same category as offsize but its effect is generally more limited to nailing or bearing surface than strength.

Shakes and splits: Shakes and splits in lumber subjected to bending reduce the resistance to shear, and therefore may be critical if located in those portions of a bending member where shearing stresses are highest. **Checks** have similar effect on a bending member but usually are less severe and seldom are critical.

Decay: Decay has an early and serious effect on strength and is difficult to judge accurately by visual inspection. It must be closely limited or entirely excluded from lumber whose strength is important.

A more intensive discussion of the factors affecting the strength of wood can be found in the American Society for Testing Materials publication "Tentative Methods for Establishing Structural Grades of Lumber," A.S.T.M. Designation D245-49T. Tables 1, 2 and 3 show the bending strength reducing effect of knots, slope of grain, and splits on 2 x 8 joists and beams.

Table 1.—STRENGTH RATIOS CORRESPONDING TO VARIOUS COMBINATIONS OF SIZE OF KNOT AND WIDTH OF FACE

2 X 8 JOISTS AND PLANK

KNOTS ON NARROW FACE			KNOTS ON CENTER LINE OF WIDE FACE			KNOTS ON EDGE OF WIDE FACE		
	Thickness			Width of face			Width of face	
Size of Knot Inches	Dressed 1 5/8"	Rough 2"	Size of Knot Inches	Dressed 7 1/2"	Rough 8"	Size of Knot Inches	Dressed 7 1/2"	Rough 8"
	Strength Ratio			Strength ratio			Strength ratio	
1/4	87	90	1/4	97	97	1/4	94	95
3/8	79	83	1/2	94	94	3/8	91	92
1/2	70	77	3/4	90	91	1/2	88	89
5/8	63	71	1	87	88	5/8	85	86
3/4	56	65	1 1/4	84	85	3/4	82	83
7/8	48	58	1 1/2	80	82	7/8	79	80
1	41	52	1 3/4	77	79	1	76	77
1 1/8	34	46	2	74	75	1 1/8	73	75
1 1/4	26	39	2 1/4	70	72	1 1/4	70	72
1 3/8	18	33	2 1/2	67	69	1 3/8	68	69
1 1/2	10	27	2 3/4	64	66	1 1/2	65	67
1 5/8	--	21	3	60	63	1 5/8	62	64
1 3/4	--	15	3 1/4	57	60	1 3/4	60	62
1 7/8	--	9	3 1/2	54	57	1 7/8	57	59
			3 3/4	51	54	2	55	57
			4	47	50	2 1/8	52	55
			4 1/4	44	47	2 1/4	50	52
			4 1/2	41	44	2 3/8	48	50
			4 3/4	37	41	2 1/2	45	48
			5	34	38	2 5/8	43	46
			5 1/4	31	35	2 3/4	41	44
			5 1/2	27	32	2 7/8	39	42
			5 3/4	24	29	3	37	40
			6	21	25	3 1/8	35	38
						3 1/4	33	36
						3 3/8	31	34
						3 1/2	29	32
						3 5/8	27	30
						3 3/4	26	29
						3 7/8	24	27
						4	22	25

Using the strength-ratio technique, we have so far developed bending strength values for well-distributed sample lots of lumber representing four species used in framing farm work buildings in the Northeast. The species included are hemlock, spruce, white pine, and red oak. To date we have inspected some 2,500 pieces of material at 32 different mills. We have limited the study to two representative sizes of dimension, namely 2 x 4's and 2 x 8's, but have included both rough and dressed lots. When complete, the study will have surveyed over 3,000 pieces.

Material surveyed has been randomly selected from stocks of native ungraded lumber offered for sale at small sawmills or lumber yards catering at least in part to the local farm trade. The product of three or four mills is represented within each size and species sampled.

In order to test and confirm field methods of determining strength ratios, we have selected groups of five or ten pieces from the lots surveyed and subjected them to machine testing at the U. S. Forest Products Laboratory. Results of these tests have indicated that our field method gives an adequate expression of strength.

Table 2.—STRENGTH RATIOS CORRESPONDING TO VARIOUS SLOPES OF GRAIN

Slope of Grain	Maximum Strength Ratio	Slope of Grain	Maximum Strength Ratio
1 in 1	8	1 in 10	61
1 in 2	16	1 in 12	69
1 in 3	24	1 in 14	74
1 in 4	32	1 in 15	76
1 in 5	40	1 in 16	80
1 in 6	45	1 in 18	85
1 in 8	53	1 in 20	100

Table 3.—STRENGTH RATIO CORRESPONDING TO VARIOUS SIZES OF SHAKE OR CHECK IN 8/4 JOISTS

Size of Shake or Check (Inches)	Strength Ratio	
	Green Lumber	Seasoned Lumber
	(Per cent)	
1/4	90	100
3/8	83	94
1/2	77	87
5/8	71	80
3/4	65	73
7/8	58	66
1	52	59
1 1/8	46	52

Planned Analysis of Data

Upon completion of the field portion of the study, early this fall, we plan to analyze the data as follows: Frequency distributions will be made of the strength ratios for each species and size of lumber, keeping data on rough and dressed material separate. A compilation of the governing defects for each species and size will also be made. The average values and standard deviation will be calculated and the extreme ranges will be noted. By mathematical methods already developed, the frequency distributions of strength ratios can be applied to the known frequency distributions of clear wood strength to give estimated frequency distributions of actual strength values in the various lots of lumber. These calculated distributions will be examined for average and probable

minimum values, and exclusion levels appropriate to farm building design. Consideration will be given to suitable working stresses for such lumber when used for framing farm work buildings.

Additional examination will be made of frequency distributions of strength ratios that would result from the application of simple stress grading rules. These rules or specifications will be such as might be shown on standard farm building plans and applied by a farmer or farm carpenter.

This is essentially a progress report on this project at this time to call attention to:

1. The field of stress grading. Information and simple techniques are available as a basis for making adequate analyses of this important Northeastern product—construction lumber.

2. Advantages of stress grading. To compete with other woods, Northeastern material must be manufactured for specific use better than ever before. Stress grading is one means of guiding a movement to put Northeastern construction lumber on a par with that of other regions, not only for rural but for urban use as well.

We have fine woods in the Northeast. This study should show how to capitalize on their inherent strength qualities in the construction field.

Discussion

Q: Can you explain or give us a demonstration of just how you determine and assign a stress ratio to any given piece of dimension lumber?

Mr. Ostrander: The stress ratio of any given piece of dimension lumber is usually determined by the *one* most critical defect in the piece, although in some cases a combination of defects, such as knot clusters or a knot in combination with wane, may determine the strength of the piece. The critical defect may be any one of the strength factors previously mentioned.

General procedure is to first inspect the pieces for the most damaging knot. As the effect of size of knot is proportional to the width of the face in which it is located, the largest knot is not necessarily the most critical. Inspection of Table 1 of this report bears this out. A three-inch knot in the middle of the wide face of a rough 2x8 indicates a relatively high stress ratio of 63 per cent. However, a two-inch knot on the edge of the wide face of a similar piece reduces the stress ratio to 57 per cent, and a one-inch knot showing on the narrow face only would reduce the stress ratio down to 52 per cent.

In the process of proper knot evaluation, one should also check for the presence of excessive slope of grain, rot, shake, and splits. If the effect of any one of these less-frequent factors is greater than that of the most critical knot, it should be measured or evaluated and the stress ratio read from the appropriate table and assigned to the piece.

Q: Have you found any particular critical strength factors occurring much more often than others in any particular size or species?

Mr. Ostrander: There appear to be no great differences in this respect between the softwood species of a given size, but differences were noted between oak and the softwoods covered in the survey. The table below shows these dlifferences.

Inspection of the table reveals that knots are the critical defect in 93 per cent of the pieces of all softwoods, 91 per cent of oak 2x4's, and only 81 per cent of oak 2x8's.

Critical knots on the narrow face are less frequent in oak than in softwoods.

Of the non-knot strength factors, slope of grain is most important except in 2x8 oak where splits were found to be quite common.

Q: Do we have standard stress grades for any of our Northeastern Softwoods? If so, why cannot these be used in farm construction?

Mr. Ostrander: We have standard stress grade specifications for eastern spruce adopted and published by the Northeastern Lumber Manufacturers Association. This association also recognizes the eastern hemlock stress grade specifications of the Northern Hemlock and Hardwood Manufacturers Association. These could be used in specifying suitable dimension lumber for farm use. The drawback is that the average small sawmill supplying material for farm use does not stress grade such material. Usually such specifications are somewhat complex and require training to apply. We hope to evolve from this study simplified rules or specifications that can be easily learned and applied by small sawmill operators and farmers.

Q: How do Northeastern dimension species compare in strength with western and southern species for the same use?

Mr. Ostrander: The basic stress values of clear lumber specimens of coast Douglas-fir and southern yellow pine are higher than any of the native woods covered in this survey. Proper design and choice of high grade native material plus the practice of selling heavier than standard sizes of native material can easily offset the advantage of higher basic stresses of imported woods.

The basic stresses (bending and shear) for clear lumber (green) under long time service at full design load for the species in question are shown below.

Species	Basic Stress in— Extreme fiber in bending P.s.i.	Maximum horizontal shear P.s.i.
Douglas-fir		
Coast Type	2200	130
Rocky Mountain	1600	120
Southern Yellow Pine	2200	160
Eastern White Pine	1300	120
Eastern Hemlock	1600	100
Eastern Spruce	1600	120
Red oak	2050	185

Q: How does shake affect strength of a piece?

Mr. Ostrander: Shake affects the strength of a piece of lumber subjected to bending by reducing the resistance to shear. Shear stress in joists or beams is greatest near the ends of a piece and at or near the neutral axis. Therefore, shake or check in joists and beams is critical only when located within this area.

Q: You mentioned that shake does not influence the bending strength, but does it not influence the stiffness of the beam?

Mr. Ostrander: The answer is yes.

Anon. Comment: The table in the paper shows the value for knots along the center line of the beam, knots along the edge of the beam, and knots along the narrow edge of the beam. In the case of knots along the narrow face, or knots along the edge of the wide face, we are concerned primarily with those knots falling within the middle third of the beam. Knots along the center line have the same value

Species and Size	Knots on narrow face	Knots on edge of wide face	Knots along center of wide face	Knots between center and edge of wide face	Slope of grain	Shake or split	Rot, wane, etc.	Total
	Per cent							
Softwoods								
2 x 4	34	34	9	16	5	--	2	100
2 x 8	25	42	6	20	4	2	1	100
Oak								
2 x 4	20	32	15	24	7	1	1	100
2 x 8	16	24	15	26	5	10	4	100

throughout the length of the beam. Knots along the wide face are ordinarily such that the values listed in the table are correct for knots falling within the center portion. However, when we get out towards the ends of the beam (the last third of length at either end) those knots can be bigger so we have to adjust for that. In other words, a one-inch knot along the edge of the beam at the center, a two-inch knot at the end, and a one-and-a-half-inch knot midway betwen would all have the same strength values.

Q: Are your specifications for farm building material going to the highest grade or not the highest grade, relative to your standard construction grades?

Mr. Ostrander: No, they won't be the highest grades.

Q: Then the agricultural engineer's problem is to determine what the strength of this material is, say spruce or hemlock. Can the designer know what the safe working stresses are of this lumber and, if so, design their building accordingly?

Mr. Ostrander: This study should give the agricultural engineer sufficient information on the strength of ungraded, locally produced dimension lumber so that he can then design farm buildings with safe working stresses.

Swelling of Paint Films in Water VII. Latex Vehicles[1]

F. L. BROWNE

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Discusses the effect of four water emulsion vehicles on the behavior of free films of paints when soaked in distilled water for three days and then redried, when soaked again for three days and redried, and when weathered before soaking for three days and redried. Measured were changes in density, absorption of water, swelling during absorption, shrinkage on redrying, loss in weight while soaking, and loss in weight while weathering.

THE BEHAVIOR OF FREE FILMS of different oil and oleoresinous vehicles with and without pigments when soaked in distilled water for 3 days and then redried was reported in the sixth paper of this series (3).[3] This seventh paper describes similar tests of unpigmented and pigmented films in latex (water emulsion) vehicles.

Vehicles and Paints Tested

Three commercial latex vehicles were chosen: an acrylic-resin emulsion, a polyvinyl acetate emulsion, and a styrene-butadiene emulsions. The emulsions contained necessary plasticizers, the nature of which was not disclosed by the makers. It should be recognized, of course, that different brands of any one of the three kinds of latex may vary considerably in their properties, particularly in absorption and swelling. For the present purpose, however, the interest is not primarily in comparison of one kind of latex with another, but rather in comparing latexes as a group with the oil and oleoresinous vehicles previously studied and in learning whether pigments exert similar effects in latex and in oleoresinous vehicles.

The pigments were basic carbonate white lead, rutile titanium dioxide, zinc oxide, and magnesium silicate of the same brands and grades used in the previous work with oil and oleoresinous vehicles. Pigmented films were made with single-pigment paints only, and always at 30 per cent pigment volume. It was not found possible, however, to make a white lead paint with the polyvinyl acetate latex, because white lead apparently broke the emulsion and a granular product resulted.

The latex paints were strictly experimental. The desire was to study films composed as nearly as possible of polymer and pigment without the complications of the several additives necessary to make practical paints. Other investigators (2, 4, to 7) indicate that additives, especially those soluble or partly soluble in water, often greatly increase the absorption of water and swelling of latex paints. Accordingly, no wetting agent, dispersing agent, antifoaming agent, bodying agent, or preservative was added except as described later in the report.

The experimental paints were made in laboratory batches of less than 1 pint, with such precautions to avoid foaming as it was possible to take without the use of additives. Most of the paints held some foam, and films made from some of them, especially those containing white lead or zinc oxide, retained some air bubbles. Nevertheless, all films proved impermeable to dry air under one-third atmosphere pressure except those of zinc oxide in acrylic resin and in polyvinyl acetate latex and titanium dioxide in styrene-butadiene latex. Paints containing one additive, methyl cellulose in the proportion of 4.5 per cent based on the nonvolatile content of the latex, were made with each of the four pigments in styrene-butadiene latex.

For comparison with the experimental paints, one commercial latex paint was tested. It was made with rutile titanium dioxide and magnesium silicate at 35.5 per cent pigment volume in a polyvinyl acetate latex with methyl cellulose and other customary additives.

Preparation of Free Films and Tests

Free films of latex vehicles and paints could not be prepared by spreading on gummed paper because the water in the latex softened the dextrine gum and the coatings usually cracked in an alligator pattern as they dried. Accordingly, all films were spread on tinplate and, after curing or curing followed by artificial weathering, were stripped by amalgamating the tinplate.

All coatings were allowed to stand 30 days after spreading to allow them to cure thoroughly. Those to be weathered were then exposed to ultra-violet

[1] A contributed paper.
[2] Maintained at Madison, Wis. in cooperation with the University of Wisconsin.
[3] Numbers in parentheses refer to literature cited.

The Author: Frederick L. Browne received B.Chem. degree from Cornell U., Ph.D. in colloid chemistry from U. of Wisconsin. He joined the Forest Products Lab staff in 1918, helped develop casein glues for wood airplanes of World War I. In 1921–22, he was a National Research Fellow at Wisconsin. Since 1929, Dr. Browne has edited the General and Physical Chemistry section of Chemical Abstracts.

light from a flaming carbon arc enclosed in Corex D glass (1,200 kilowatt-hours of electric input) and sprayed with distilled water three times each hour for a period of 15 days.

Unweathered films of each vehicle and paint were subjected to two successive cycles of soaking in distilled water for three days followed by redrying over calcium chloride. This was done because it was observed that some films of latex paint absorb much less water and swell less in the second soaking than in the first, presumably because the first soaking removes soluble ingredients that stimulate absorption and swelling. Weathered films of each vehicle and paint, which were always well leached during the weathering process, were subjected to one cycle only of soaking for three days and redrying.

Dry films of latex paints usually begin to absorb water and swell much more rapidly than oil or oleoresinous paint films. For that reason great care was taken to make the weighings of dry latex films as quickly as possible after immersion.

Wet films of latex paints, when blotted to remove free water, were found to lose weight more rapidly by evaporation while being weighed than was the case with films of oil or oleoresinous paints. The wet films of latex paint were therefore placed in tared weighing bottles immediately after blotting.

In all other respects the methods of testing were the same as those previously described for the oil and oleoresinous paints.

Results with Experimental Paints

The results with the experimental vehicles and paints are reported in Table 1.

Density: The relatively large increase in density that was characteristic of oil paints during their initial drying period (3) was conspicuously lacking among the latex vehicles and paints. In fact, only 5 of the 18 latex vehicles and paints gained at all in density during drying and curing, and for 4 of the 5, the gain was no greater than 3 per cent. The clear film of acrylic latex was 6.4 per cent denser than the nonvolatile part of the liquid latex, but the films of clear polyvinyl acetate and styrene-butadiene dried and cured without change in density.

On the other hand, 11 of the 15 latex paints made films of lower density than the nonvolatile part of the liquid paint. Decrease in density during initial drying and curing probably indicates the formation of porous films that enclose voids. This interpretation is consistent with the finding that all latex paints exhibited less than 100 per cent swelling efficiency, and the swelling efficiency usually was particularly low when the decrease in density on drying and curing was more than 4 per cent.

The densities of the nonvolatile portions of the liquid latexes and paints were as follows: acrylic latex, 1.09; polyvinyl acetate latex, 1.16; styrene-butadiene latex, 1.02; acrylic paints pigmented with white lead, zinc oxide, titanium dioxide, and magnesium silicate, respectively, 2.80, 2.44, 2.02, and 1.62; polyvinyl acetate paints pigmented with zinc oxide, titanium dioxide, and magesium silicate, respectively, 2.19, 1.95, and 1.67; styrene-butadiene paints pigmented with white lead, zinc oxide, titanium dioxide, and magnesium silicate, respectively, 2.76, 2.39, 1.97, and 1.57; and styrene-butadiene with methyl cellulose pigmented with white lead, zinc oxide, titanium dioxide, and magnesium silicate, respectively, 2.77, 2.33, 1.98, and 1.58.

When soaked in water for the first time, all films decreased in density by an amount roughly proportional to the absorption of water except the films of titanium dioxide and of zinc oxide in polyvinyl acetate, both of which gained in density despite large absorptions of water. The two exceptions were the paints whose films decreased most markedly in density during drying and curing. Hence the gain in density when soaked in water may indicate a reduction in volume of voids brought about by release of internal stresses in the films when they are plasticized by absorbed water.

When redried after the first soaking, all but four films regained or, more often, exceeded their density before soaking. Increase in density and decrease in volume are to be expected as a result of loss of water-soluble ingredients of low density to the soaking water. Of the four films that failed to regain the density before soaking, two fell short by less than 2 per cent and contained either no pigment or the light pigment magnesium silicate. The other two, zinc oxide in styrene-butadiene with and without methyl cellulose, fell short by 5.7 and 4.8 per cent, respectively, and also were larger in volume after redrying than before soaking.

When soaked in water a second time, the density of most films decreased, again roughly proportionally to the absorption of water. The exceptions were films that had originally dried with a density less than that of the nonvolatile in the liquid paint and had not yet regained that density after the first soaking and redrying. When redried after the second soaking, all but three films regained or only very slightly exceeded their density before the second soaking. The three exceptions, titanium dioxide in styrene-butadiene, zinc oxide in acrylic resin, and magnesium silicate in styrene-butadiene, were films that remained larger in volume after redrying than before the second soaking.

Weathering increased the density of all films except those of zinc oxide in acrylic resin, in styrene-butadiene, and in styrene-butadiene with methyl cellulose. These films decreased substantially in density. The three exceptions were notable also for very low swelling efficiencies after weathering, 32, 29, and 40 per cent, respectively, which indicates that weathering increased the volume of voids within the films.

When soaked in water, all but five weathered films decreased in density. All five of the films that failed to decrease in density were films that, unlike the others, were still below the density of the non-volatile in the liquid paints even after weathering. Four of the five were paints whose unweathered films had failed to decrease in density during one or both of the soaking periods, and four of the five had, as unweathered films, increased in volume after redrying following one of the soaking periods. These five films, then, were porous films that tended to become less porous when soaked in water. When the weathered films were redried after soaking, they all regained or very nearly regained their density before soaking except one, zinc oxide in polyvinyl acetate, which retained 2.9 per cent greater volume after soaking.

The observations of density changes indicate that the latex vehicles and paints, although subject to less changes during film formation and weathering from oxidation, contraction, and decomposition of the vehicle constituents themselves than are the oil and oleoresinous paints, nevertheless are subject to a greater extent than the oil paints to changes in film structure, particularly to formation of voids within the films and alteration in the volume of voids.

Absorption of Water: Clear films of acrylic resin in both the first and second soakings of unweathered and weathered film were remarkably high in absorption, more than twice as high as the films of unbodied linseed oil previously reported (3). Polyvinyl acetate film before weathering absorbed less than unbodied linseed oil and about as much as films of bodied linseed oil or of alkyd resin. After weathering, however, polyvinyl acetate film, unlike the oil and oleoresinous films, became very highly absorptive.

Unweathered styrene-butadiene film in the first soaking was about equal

to unweathered polyvinyl acetate, but in the second soaking the absorption by styrene-butadiene film was very low. Failure of the styrene-butadiene film on weathering precluded measurement of its absorption after weathering, which may indicate that weathering greatly increased its absorption as it did that of clear acrylic resin and polyvinyl acetate. Weathering, then, seems to increase the absorption of water by clear latex films.

Pigmentation altered the absorption of all latex vehicles, usually significantly. In acrylic latex, the clear film of which was very absorptive, all pigments except zinc oxide greatly reduced absorption. Zinc oxide increased the absorption if allowance is made for the fact that only 70 per cent of the pigmented film was acrylic resin. Unweathered pigmented films of polyvinyl acetate or styrene-butadiene were always higher in absorption than the clear films of the same latex, and among them, the films with zinc oxide were highest in absorption. Thus zinc oxide seems to have the same effect of stimulating high absorption in latex paints that it has in oil and oleoresinous paints.

White lead, however, behaved differently in the latex paints than it did in oil paints. In acrylic latex, white lead did not reduce absorption nearly as much as titanium dioxide did,

Table 1.—DATA FOR FREE FILMS OF DIFFERENT KINDS OF LATEX VEHICLES WITH AND WITHOUT PIGMENTS WHEN SOAKED IN WATER FOR THREE DAYS AND REDRIED, WHEN SOAKED AGAIN FOR THREE DAYS AND REDRIED, AND WHEN WEATHERED BEFORE SOAKING FOR THREE DAYS AND REDRIED—CHANGES IN DENSITY; ABSORPTION OF WATER AND SWELLING IN VOLUME, AREA, AND THICKNESS; SWELLING EFFICIENCY, SHRINKING IN VOLUME, AREA, AND THICKNESS WHEN REDRIED; LOSS IN WEIGHT WHILE SOAKING; AND LOSS IN WEIGHT WHILE WEATHERING

Kind of latex vehicle	Stage in cycle of testing	Weight loss while weathering S_1/V_0	Density of film: Dry	Swollen in water	Redried	Initial thickness of film T_0	Absorption of water A/V_0	Swelling: In volume ΔV_s	In area ΔQ_s	In thickness ΔT_s	Swelling efficiency $\frac{\Delta V_s V_0}{A}$	Redried: Volume ΔV_r	Area ΔQ_r	Thickness ΔT_r	Loss in weight soaking S_2/V_0
		Percent				Mils	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Gr. per 100 cc.
CLEAR VEHICLES CONTAINING NO PIGMENT															
Acrylic	First soak		1.16	1.10	1.16	3.9	57.9	57.5	42.7	9.7	99	-0.5	-2.2	+1.5	1.2
	Second soak		1.16	1.10	1.16	4.0	52.0	51.7	35.1	11.8	99	-.5	0	-.5	.3
	Weathered	5.3	1.17	1.09	1.16	3.6	68.7	68.2	34.9	24.7	99	0	+3.8	-3.9	.5
Polyvinyl acetate	First soak		1.16	1.15	1.16	3.8	8.2	8.1	5.9	-5.5	99	-8.2	-6.3	-2.1	9.3
	Second soak		1.16	1.16	1.16	3.7	8.1	7.8	4.0	3.2	96	-.3	+1.1	-1.6	.3
	Weathered	9.1	1.17	1.12	1.17	3.7	48.9	48.9	28.0	15.6	100	-1.2	+5.9	-6.7	9.1
Styrene-butadiene[1]	First soak		1.02	1.00	1.00	4.4	8.7	8.6	9.2	-6.8	99	-6.7	-2.0	-8.6	7.8
	Second soak		1.00	1.00	1.00	4.2	3.3	3.1	2.7	0	94	-.2	-.6	-3.6	1
BASIC CARBONATE WHITE LEAD, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30															
Acrylic	First soak		2.78	2.56	2.82	5.2	22.7	18.7	5.7	10.5	82	-1.8	0	-1.9	2.0
	Second soak		2.82	2.64	2.82	5.1	16.9	13.2	3.7	8.7	78	-.2	-.3	0	.4
	Weathered	4.5	2.89	2.33	2.89	4.4	47.2	44.2	5.6	36.3	94	-.3	+.6	-1.1	1.0
Styrene-butadiene	First soak		2.74	2.61	2.78	4.9	11.9	11.0	3.4	3.7	92	-3.6	-.9	-2.8	5.5
	Second soak		2.78	2.65	2.79	4.8	9.2	8.9	1.5	6.3	97	-.5	-.4	-.6	.5
	Weathered	8.9	2.82	2.58	2.82	4.4	16.7	16.1	8	14.6	96	-.7	-.1	-.5	2.0
Styrene-butadiene plus methyl cellulose	First soak		2.65	2.17	2.72	3.9	51.5	47.4	3.1	12.1	92	-5.6	0	-5.4	9.4
	Second soak		2.72	2.33	2.73	3.7	35.7	34.7	1.7	29.1	92	-1.2	-1.0	-.3	1.1
	Weathered	11.1	2.75	2.58	2.75	3.7	15.0	12.7	1.3	9.5	85	-1.5	-.6	-1.1	4.0
RUTILE TITANIUM DIOXIDE, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30															
Acrylic	First soak		2.08	2.03	2.08	4.9	7.0	6.4	6.2	-1.4	91	-1.6	-3.1	+1.4	2.8
	Second soak		2.08	2.03	2.09	5.0	7.3	6.7	4.2	1.8	92	-.7	-.2	-.4	.8
	Weathered	3.0	2.09	2.04	2.11	5.3	6.5	6.4	2.8	1.9	99	-1.2	-.8	-.2	1.1
Polyvinyl acetate	First soak		1.71	1.89	1.77	4.8	23.0	6.3	6.0	5.0	27	-5.7	-5.2	-.6	3.6
	Second soak		1.77	1.91	1.78	4.8	21.6	4.2	5.2	-1.7	19	-.5	-.1	-.4	.2
	Weathered	4.2	1.80	1.98	1.82	3.8	15.0	13.9	.4	11.9	93	-1.8	-2.1	+.5	.6
Styrene-butadiene	First soak		1.95	1.88	1.96	5.1	10.9	9.9	6.9	.2	91	-3.0	-2.8	-.2	4.6
	Second soak		1.96	1.93	1.95	5.1	6.2	4.3	3.2	1.6	69	+.6	-.3	+.8	.3
	Weathered	1.5	2.00	1.89	1.99	4.8	15.2	13.7	1.1	12.6	90	0	0	+.4	.4
Styrene-butadiene plus methyl cellulose	First soak		1.93	1.84	1.96	3.7	15.3	14.8	10.1	-1.1	97	-6.2	-4.9	-1.4	7.8
	Second soak		1.96	1.87	1.97	3.6	12.5	12.0	6.2	5.2	96	-.2	+.3	-.5	.2
	Weathered	1.8	2.01	1.98	2.02	3.7	5.9	5.0	1.4	2.7	85	-1.4	-.9	-.5	2.1
ZINC OXIDE, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30															
Acrylic	First soak		2.48	2.06	2.49	2.8	50.5	45.2	2.9	39.4	90	-1.8	-1.5	-.4	3.9
	Second soak		2.49	2.08	2.42	2.8	47.8	40.0	2.0	39.4	84	+2.2	-.9	+2.9	1.1
	Weathered	14.3	1.99	2.14	2.00	3.6	42.5	13.7	.6	12.1	32	-.9	-.6	-.3	1.6
Polyvinyl acetate	First soak		1.81	1.95	2.40	3.5	49.7	42.6	5.8	11.0	86	-25.0	-6.2	-20.0	3.7
	Second soak		2.40	1.95	2.40	2.8	64.2	55.2	1.9	52.0	86	-2.2	+2.9	-3.6	2.1
	Weathered	22.5	2.67	2.11	2.58	2.8	61.7	54.3	.9	54.1	88	+2.9	-.6	+4.3	2.1
Styrene-butadiene	First soak		2.31	2.17	2.19	5.0	20.4	10.5	4.0	9.4	52	+3.3	-3.0	+6.2	4.9
	Second soak		2.19	2.19	2.20	5.3	17.1	8.1	2.9	-4.3	47	-.8	-.8	+.4	4
	Weathered	.7	2.13	2.19	2.12	6.0	18.7	5.4	.5	4.9	29	+.4	-.2	+.7	7
Styrene-butadiene plus methyl cellulose	First soak		2.10	1.97	2.00	4.5	27.7	15.6	4.7	19.6	57	+1.4	-2.4	-4.0	7.0
	Second soak		2.00	2.01	2.00	4.7	23.4	11.5	3.2	7.9	49	-.4	-.5	+.2	.7
	Weathered	6.9	1.97	2.06	2.01	4.6	23.7	9.5	.9	5.6	40	-3.3	-.4	+2.7	2.7
MAGNESIUM SILICATE, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30															
Acrylic	First soak		1.57	1.45	1.57	4.2	30.2	29.5	15.0	12.0	98	-1.3	0	-1.0	2.2
	Second soak		1.57	1.47	1.58	4.2	23.5	23.0	12.2	8.9	98	-.9	-.2	-.4	.9
	Weathered	18.3	1.80	1.36	1.81	4.6	119	120	20.6	81.4	101	-1.4	+14.0	-13.4	1.6
Polyvinyl acetate	First soak		1.67	1.65	1.71	4.6	8.9	8.4	4.3	-2.6	94	-6.8	-4.2	-1.7	9.0
	Second soak		1.71	1.66	1.71	4.5	8.9	8.5	2.9	5.1	96	-.4	0	-.4	.3
	Weathered	7.7	1.72	1.61	1.73	4.4	18.2	18.2	5.1	6.5	100	-1.8	-.8	-5.0	1.9
Styrene-butadiene	First soak		1.44	1.41	1.43	4.7	13.3	10.6	3.4	3.6	80	-3.4	-.8	-2.5	5.9
	Second soak		1.43	1.43	1.42	4.6	8.3	5.0	1.3	3.9	60	+.1	-.2	0	.4
	Weathered	1.0	1.51	1.51	1.50	5.8	10.6	6.8	.7	4.7	64	-1.1	-.6	-.5	2.1
Styrene-butadiene plus methyl cellulose	First soak		1.58	1.49	1.60	3.7	20.6	20.4	7.0	6.0	99	-7.2	-3.0	-4.4	9.2
	Second soak		1.60	1.53	1.60	3.5	15.5	15.1	4.6	9.7	98	-.6	-.3	-.3	.8
	Weathered	8.9	1.65	1.62	1.68	3.5	8.1	8.6	.6	4.8	106	-2.9	-.8	-2.0	3.0

[1] The paint cracked and scaled too badly during weathering to permit further study.

whereas in styrene-butadiene, white lead increased absorption more than titanium dioxide did, and in styrene-butadiene containing methyl cellulose, white lead increased absorption much more than even zinc oxide did.

Titanium dioxide produced the lowest absorption of any pigment in all latex vehicles except polyvinyl acetate in which still lower absorption was produced by magnesium silicate. Addition of methyl cellulose to pigmented films of styrene-butadiene always increased the absorption of the unweathered films.

Absorption during the second soaking of unweathered films was usually less than during the first soaking. The chief exception was zinc oxide in polyvinyl acetate, for which absorption was distinctly higher in the second than in the first soaking. Absorption by titanium dioxide in acrylic latex was very slightly higher and absorption by magnesium silicate in polyvinyl acetate was the same in the second as in the first soaking.

Weathering decreased the absorption by 9 and increased the absorption by 6 of the 15 pigmented films. The increase on weathering was very great for magnesium silicate in acrylic latex and in polyvinyl acetate, and for white lead in acrylic latex. The decrease was very great for white lead, titanium dioxide, and magnesium silicate in styrene-butadiene containing methyl cellulose. No explanation for these differences in the effect of weathering can be offered at present.

Swelling: In general, films of latex paints differed from the oil and oleoresinous paints previously reported (3) in that the unweathered latex films never swelled in volume quite so much as their absorption of water during the 3-day soaking periods would indicate. That is, the swelling efficiency was always less than 100 per cent and usually was considerably less. Moreover, the swelling efficiency for the second soaking period was usually less than that for the first soaking period. Low swelling efficiency is considered indicative of porosity, or voids within the film in which free water can be held and cause no swelling. Published electron photomicrographs (1) of latex films reveal such porosity due to incomplete fusion of the latex droplets and gathering of pigment in the interfaces between droplets. Some of the water-soluble substances leached by the first soaking may likewise come from these interfaces and increase the void volume for the next soaking.

Unpigmented latex films gave less evidence of porosity than pigmented films. For the unpigmented films, the swelling efficiency in the first soaking was 99 per cent. In the second soaking of acrylic latex, which lost little soluble material in the first soaking, the swelling efficiency remained at 99 per cent, but for films of polyvinyl acetate and of styrene-butadiene, which had higher solubility in the first soaking, the efficiency dropped to 96 and 94 per cent, respectively. For weathered polyvinyl acetate film, however, the swelling efficiency was 100 per cent.

Among unweathered pigmented films, only three attained 97 to 99 per cent swelling efficiency in the first soaking: magnesium silicate in acrylic resin and in styrene-butadiene with methyl cellulose, and titanium dioxide in styrene-butadiene with methyl cellulose. For titanium dioxide in polyvinyl acetate, the efficiency was only 27 per cent. For zinc oxide in acrylic resin, polyvinyl acetate, styrene-butadiene, and styrene-butadiene with methyl cellulose, the swelling efficiency was 90, 86, 52, and 57 per cent, respectively. In the second soaking period, the swelling efficiency for pigmented films was usually less than in the first soaking, sometimes much less. For three films, however, the two efficiencies were equal and for three the efficiency was somewhat higher in the second than in the first soaking.

After weathering, the swelling efficiency of films pigmented with zinc oxide was usually lower, and that of films with other pigments was sometimes lower and sometimes higher, than the swelling efficiency of the corresponding unweathered films. There seems to be no clear evidence of correlation with other properties of the films except perhaps that a relatively large decrease in swelling efficiency after weathering seems to be associated with a significant decrease in film density. Apparently, weathering may either increase or decrease the volume of voids in pigmented latex films.

All latex films swelled in area during the 3-day soaking periods, but the areal swelling showed even greater lack of proportionality to volumetric swelling than was previously observed with oil and oleoresinous paints (3). Areal swelling ranged from 7 per cent to 107 per cent of volumetric swelling for unweathered films soaked for the first time, from 5 per cent to 87 per cent for unweathered films soaked for the second time, and from 2 per cent to 57 per cent for weathered films. In the second soaking of unweathered films, the areal swelling was usually a lower percentage of the volumetric swelling than in the first soaking, and for weathered films, the areal swelling was usually a still lower percentage of the volumetric swelling.

The discrepancy in proportionality of areal to volumetric swelling was compensated by reciprocal variation in the proportionality of swelling in thickness to swelling in volume. In seven extreme cases, the thickness of unweathered films actually decreased during the soaking period.

Shrinkage on Redrying: On redrying after the first soaking of unweathered latex films, all but two shrank to a volume less than that before soaking. Such shrinkage is attributable chiefly to the fact that all films lost appreciable amounts of soluble substances to the soaking water. The films of zinc oxide in styrene-butadiene and in styrene-butadiene with methyl cellulose remained larger in volume and also lower in density after redrying than before soaking, which indicates an increase in volume of voids within the films. On redrying after the second soaking, most films shrank still further, though less markedly than after the first soaking, which indicates smaller losses of soluble substances. Films of titanium dioxide and of magnesium silicate in styrene-butadiene and of zinc oxide in acrylic resin, however, gained slightly in volume and lost in density.

Redried weathered films likewise exhibited a slight loss in volume, except for clear acrylic resin and titanium dioxide in styrene-butadiene, which exhibited no change in volume but a slight loss in density and in soluble substances, and zinc oxide in polyvinyl acetate and in styrene-butadiene, which gained in volume and lost in density.

Shrinkage in area during redrying was not at all proportional to shrinkage in volume. Most films shrank proportionately less in area and correspondingly more in thickness than they did in volume whereas many others shrank proportionately more in area and less in thickness. In this respect, even films of the same paint often behaved differently on redrying after the first and second soakings of the unweathered film and after soaking of the weathered film.

Loss in Weight While Soaking: During the first soaking of unweathered films, from 1.2 to 9.4 grams of soluble substances per 100 cubic centimeters of film were lost to the soaking water. The loss was less than 3 grams per 100 cubic centimeters for only 4 of 18 films. During the second soaking the losses were less and ranged from 0.1 to 2.1 grams per 100 cubic centimeters, with only 3 losses over 1 gram per 100 cubic centimeters. Thus most of the soluble material seems to be in the latex films before the first soaking.

Whether the loss during the second soaking is due to incomplete leaching the first time or to further formation

of soluble substances by hydrolysis while the film is in water is as yet uncertain. The loss from weathered films was always less than that from unweathered films when soaked for the first time but greater than that from unweathered films soaked the second time. Styrene-butadiene films containing methyl cellulose always lost more soluble material than similarly pigmented films of styrene-butadiene without methyl cellulose at the same stage of the testing program.

Pigmentation always increased the solubility of acrylic-resin films but usually decreased the solubility of polyvinyl acetate or styrene-butadiene films.

Loss in Weight While Weathering: All films lost weight during weathering, usually substantially. The losses are attributed mainly to leaching of water-soluble substances by the water spraying in the weathering cycle.

Pigmentation greatly altered the weathering losses. Titanium dioxide caused low weight losses in all latexes. Zinc oxide caused remarkably low loss in styrene-butadiene, larger loss in styrene-butadiene with methyl cellulose, and very high loss in acrylic resin and in polyvinyl acetate. Magnesium silicate caused very low loss in styrene-butadiene, fairly high losses in styrene-butadiene with methyl cellulose and in polyvinyl acetate, and very high loss in acrylic resin. With white lead, the loss was moderate in acrylic resin, fairly high in styrene-butadiene, and still higher when the styrene-butadiene contained methyl cellulose.

Weathering losses in films of styrene-butadiene were always higher when the films also contained methyl cellulose.

Results with a Commercial Paint

Table 2 shows the results of tests on films made with a commercial latex paint intended for exterior use.

The density of films prepared with the commercial paint was less than the density of the nonvolatile in the liquid paint, and the swelling efficiency of the unweathered film was less than 100 per cent. The film was therefore somewhat porous, as were some of the experimental paints. The commercial paint was free from foam and made smooth films that contained no observable air bubbles. After weathering, the film density was no greater and perhaps a trifle less than before weathing. When soaked in water, the density of both unweathered and weathered films decreased roughly in proportion to the quantity of water absorbed. On redrying, the unweathered film regained the density before soaking but no more, whereas the weathered film increased nearly to the density of the nonvolatile in the liquid paint and its swelling efficiency reached 100 per cent.

The unweathered film absorbed 75.9 per cent of water by volume when soaked for three days. Among the experimental paints, the highest absorption for an unweathered film was 64.2 per cent (zinc oxide in polyvinyl acetate). Titanium dioxide in polyvinyl acetate absorbed 23.0 per cent, and magnesium silicate in polyvinyl acetate absorbed 8.9 per cent. Although the polyvinyl acetate latexes were not the same in the commercial and experimental paints, it is reasonable to conclude that the additives necessary in commercial latex paints materially increase the absorption of water by their films. In agreement with that conclusion, the solubility of the unweathered film of commercial paint was relatively high. Weathering reduced the solubility and absorption of the film of commercial paint to about the same levels as those of the weathered films of experimental polyvinyl acetate paints pigmented with titanium dioxide or magnesium silicate.

The remaining data of Table 2 confirm the essential similarity in behavior of the commercial and experimental paints when due allowance is made for the effect of the additives in the commercial paint. No measurements were made when the unweathered film of commercial paint was subjected to a second soaking and redrying, but it was observed that absorption and swelling were much less in a second soaking than in the first.

Conclusions

During film formation and curing, latex vehicles and paints undergo little or no shrinkage in volume or increase in density from the oxidation, contraction, and loss of decomposition products that characterize oil and oleoresinous paints. Instead, the latex vehicles and paints tend to form porous films that contain voids, as indicated often by a density less than that of the nonvolatile ingredients of the liquid paint and by a swelling efficiency in water of less than 100 per cent. The volume of voids may change when the films absorb water and dry again or when the films are weathered artificially. There may be a reduction in void volume, perhaps by release of internal stresses when water plasticizes the film, or an increase in void volume, which seems to be particularly likely to occur when the film contains zinc oxide.

Latex films absorb water on soaking and give it up again on redrying much more rapidly than oil or oleoresinous paints. Latex films, like oil and oleoresinous films, vary greatly in the quantity of water they will absorb in three days of soaking, and the absorption is greatly affected by pigmentation. Some pigments increase and others decrease the absorption. Among the pigments, zinc oxide greatly increases absorption of latex films just as it does that of oil and oleoresinous films. White lead, which minimizes absorption by oil films, stands midway among the pigments in its effect in latex films. Titanium dioxide greatly reduced absorption in acrylic latex but was less effective in polyvinyl acetate and styrene-butadiene films.

Absorption is greater in styrene-butadiene films when they also contain methyl cellulose than when they are free from that water-soluble substance. Likewise, absorption is less for all latex films during a second soaking than it was in the first, presumably because the first soaking removes much water-soluble material. Artificial weathering seems to increase the absorption of some latex films and to reduce that of others; perhaps there is a balance between production of water-soluble decomposition products and their removal by leaching.

Table 2.—DATA FOR FREE FILMS OF A COMMERCIAL POLYVINYL ACETATE LATEX PAINT BEFORE AND AFTER WEATHERING

Item	Unweathered film	Weathered film
Density of nonvolatile in liquid paint, 2.18		
Density of dry film	2.08	2.07
Density of film when soaked in water	1.62	2.02
Density of redried film	2.08	2.15
Initial thickness of film, mils	3.3	3.2
Absorption of water, per cent by volume	75.9	12.5
Swelling in volume, per cent	73.8	12.5
Swelling in area	36.2	5.1
Swelling in thickness, per cent	25.0	3.1
Swelling efficiency, per cent	97	100
Change in volume on redrying, per cent	-3.8	-4.7
Change in area on redrying, per cent	+4.3	0.6
Change in thickness on redrying, per cent	-7.3	-4.3
Loss in weight during weathering, grams per 100 cubic centimeters	——	9.4
Loss in weight during soaking, grams per 100 cubic centimeters	7.6	1.6

The volumetric swelling of latex films, especially pigmented films, is usually slightly to considerably less than the volume of absorbed water, probably because some absorbed water is held in voids within the film, where it causes no swelling. The void volume is often increased by leaching the first time the film is soaked and redried, so that the swelling efficiency becomes still lower in a second soaking. On weathering, some latex films become more porous and others less so, as indicated by the swelling efficiency. Zinc oxide, however, usually increases the porosity.

When latex films are redried after soaking, the volume tends to be less than before soaking in accordance with the loss of soluble substance to the soaking water. Sometimes, however, especially if the film contains zinc oxide, such shrinkage may be more than offset by increase in void volume so that the redried volume exceeds the volume before soaking. With latex films, as with oil and oleoresinous films, swelling and shrinking in area may be proportionately larger or smaller than swelling and shrinking in volume, with compensating variation in the changes in film thickness.

Much more soluble matter is leached from latex films during the first soaking in water than during the second soaking, though the fact that there was always some further loss in the second soaking suggests that there may be slow formation of soluble substances by hydrolysis while the film is in water. The solubility and loss of weight of weathered films show that decomposition goes on during weathering and is materially affected by the presence and nature of pigments. Titanium dioxide seems to reduce the loss of weight during weathering. Zinc oxide and magnesium silicate seem to increase the weight loss from acrylic and polyvinyl acetate films but reduce the loss from styrene-butadiene films.

The absorption and swelling of the experimental paints used in this study were probably much less than is to be considered normal for practical latex paints because of the exclusion of water-soluble or water-absorptive additives from the experimental paints, except for the methyl cellulose in some of the styrene-butadiene paints. The inclusion of methyl cellulose increased absorption and swelling, and the one commercial latex paint tested, which contained methyl cellulose and other customary additives, was much higher in absorption and swelling than the experimental paints.

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Planer Feeding Difficulties[1]

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ROUGH LUMBER, particularly various types of hardwood, often feeds through a thicknessing planer with difficulty. The chief part of the difficulty arises from warpage, which introduces various small waves and kinks. Much crookedness in rough lumber is readily visible to the eye, but there are many very short and relatively-small kinks which the eye ordinarily would not detect. Nevertheless, these cause definite feeding trouble.

In many instances, such kinks or crooks may be sufficiently great to cause feeding trouble at a planer where lower rolls are finely set. Lower rolls in a thicknessing planer should not be set any higher above the level of the platens than necessary. But actual line contacts obtained by the rolls are the only points where there is a forward feeding impulse.

Therefore, wherever the hollow portion of a kink or crook bridges over a lower roll, the rough surface of the material obtains practically a solid bearing on the planer platens, with nothing tending to move it until it can be fed farther forward. This is the cause of boards hesitating in the planer, and in some instances stalling. Many times it is difficult to get a board started through the machine again after it has stalled.

Fig. 1.—Single surfacer incorporating a micrometer simultaneous height adjustment for all lower rolls, operating in the plant of Wahlfeld Mfg. Company, Peoria, Ill. Photo courtesy Buss Machine Works, Holland, Mich.

Simultaneous Micrometer Roll Adjustment

Some planers are equipped with a simultaneous micrometer adjustment for all the lower rolls, which provides means for elevating these rolls a positive and sensitive amount, with very little trouble for the operator. This easily-made adjustment has proven a great boon for many planer operators who have found it necessary to use the same machine for both preliminary and finish dressing, as is necessary in some small plants.

Obviously, if one has a lot of rough lumber to dress, and can easily and sensitively raise the lower rolls a uniform amount with little trouble, it is just as easy to lower them again to a consistent elevation point when one returns to a finish-dressing job. Thus, an operator is enabled to do high-class work and still have a minimum amount of trouble in planing rough lumber.

[1] A contributed article.

A Review of Sawmill Developments in the Northeast[1]

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In today's changing economy, new developments in sawmilling are rapidly becoming a necessity for the continued profitable operation of many mills in the Northeast. Recent developments are discussed for the entire milling operation, from the time the log enters the yard until it leaves the yard as lumber.

Introduction

THE LAST FIFTY YEARS have revealed a phenomenal growth in the technological and industrial development of our nation. Many of us can remember when the automobile and the airplane were but an imaginative inventor's phantasy, never dreaming that today's family car and four-engined transport would become an integral part of our modern way of life.

Comparatively speaking, no such great technological advancements can be acclaimed by the sawmilling industry, except for the relatively few big mills in the south and far west. Little progress has been made in either the development or adaptation of new methods of milling in the typical small mill common to the Northeast, except perhaps the replacement of the steam engine by the diesel power unit and the babitt bearing by the roller bearing. Otherwise, the basic sawmill is about the same today as fifty years ago.

The fact that so little has changed in sawmilling methods during the last few decades emphasizes even more the dire need for new machines and better application of existing machinery.

A census of all mills in the Northeast (that is, in New England and New York state) reveals an astonishing figure in excess of 3500. Only 1 per cent of these are band mills, the remainder being circular. Ten per cent cut one million or more feet, the rest less. Of the total listed, only 30 per cent can be called stationary. It can also be assumed that the remaining 70 per cent, being mostly portable, fall into the category cutting less than one million feet annually.

[1] Presented at meeting of Northeast Section, FPRS, April 28–29, 1955, in Glens Falls, N. Y.

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Need for New Sawmill Developments

Our gradual nationwide increase in population with its corresponding increase in living standards, high wages, and shorter working hours has caused the cost of lumber production to accelerate faster than the lumber price structure. Consequently, many mill men, feeling the pressure of shrinking profits, have now been compelled to look for some sort of relief. Cutting wages in the face of a general economic boom would be suicidal, so the only remaining alternative is a reduction in operating costs. It is this desire to lower operating costs that has increased the interest in new machinery and methods.

Improvements in small sawmills are necessarily slow in coming, because of the fact that the cost of new machinery and changes in methods must be charged off on a relatively small output. Any changes, therefore, must be gradual and relatively inexpensive, guaranteeing either an immediate increase in production or a saving in cost, or both. In hardwood production, it is equally important to improve the quality of the lumber as well as to increase the output per man-hour.

Since the average millman builds a new sawmill about once in a lifetime, he generally gets along with what he obtained at the start. He is often reluctant to accept any revolutionary innovations, especially if they are expensive, but there is no excuse for him not to recognize the need for improving his present plant, when necessary, and then to do something about it. It is possible that the answer to many of his problems can be found in the new and improved equipment coming on the market for the use of small as well as large mills. Fork-lift trucks, powered log decks, log turners, air dogs, electric set works, hydraulic carriage drives, live rolls, transfer chains, trimmers, and lumber stackers expressly engineered and priced for the small mill are available today. More lumber per man per day is not just wishful thinking for the progressive millman; it is already a reality.

The process of sawmilling can be assumed as commencing when the log enters the mill yard and ending when the lumber leaves the yard. Briefly, this would entail piling and sorting logs in the yard, cleaning or debarking prior to sawing, the transfer of logs from the yard to the head rig, the actual sawing, then the edging, trimming, grading and piling of the lumber, and the disposal of waste. From the piles, the lumber can be marketed directly or processed further in the drying yard, kiln, or planing mill.

Yard Handling: Starting with the yard, probably the most important piece of equipment of rather recent introduction is the fork-lift truck. The use of this machine or a similar crawler-type lift has greatly simplified the handling and piling of logs as well as lumber. One man and a fork-lift can do as much work in a yard today as six men could before. He can easily handle all the logs required by the head saw during the day and still find plenty of time to pile or load the lumber produced without ever leaving his seat or straining himself.

Log Cleaning: In the past, clean logs for the head saw usually meant a log pond. Today, however, we have several machines capable of doing the job. The mechanical rosser, although not new, does a good job of cleaning off grit and bark just ahead of the cut as the log proceeds into the saw. For the small mill with a moderate budget desiring more efficient cleaning, a high pressure steam cleaner is now available. This cleaner is versatile in that it can melt frozen mud and ice in winter with its steam jet and it can be converted to a high pressure water spray for summer use. Several of these cleaners are now in successful use in the Northeast, and operators claim a substantial increase in daily lumber output due to less down time for filing or saw changing.

Where production is sufficiently high and a market is available for pulpwood in the form of chips, a log

debarker not only supplies clean logs to the saw, but also can return a fair income from what was previously considered waste. A debarker by itself is not economically feasible, but when coupled with the proper slab conveyors, chippers, screens, and chip conveyors can well pay off the rather high initial cost. Some of these debarkers work on the simple mechanical process of beating or chipping the bark off as the log passes through the debarker. Others direct high pressure water jets at the passing logs. Both types appear equally effective, the latter principle being used also to remove bark from slabs and edgings in a smaller version of the log debarker.

Recovery of chips does not necessarily require all the equipment listed above. Some sawmills are shipping unscreened chips (for screening at the paper mill) and some are even chipping residues from unbarked logs (by having the chipper-feeder select relatively bark-free material). A sawmill can begin chipping with less than a complete set-up and plow back earnings into additional equipment.

Log Deck: Much improvement has been made in many small mills in the handling of logs on the deck. Log pulls, of course, are not new, but live decks with several chains feeding the logs transversely to the carriage are rather new for the small mill. These chains are powered by a sawyer-controlled gear reducer or in some cases a hydraulic motor, and when coupled with a log turner can eliminate the need for a deck man.

Carriage: Probably the greatest improvements can be found in the new carriages on the market today. Several manufacturers are now offering totally automatic hydraulic or air-electric carriages in which off-setting, dogging, and setting are all done by the sawyer. Greater speed and accuracy and the elimination of a setter or dogger, or both, is claimed for this carriage.

Electric predetermined set-works, in which the sawyer can select the next board setting while the saw is still in the cut, can yield more lines per minute with the same rate of feed, because the momentary stop necessary for manual setting is eliminated. Exclusive carriage control by the sawyer can now be obtained with hydraulic- or solenoid-activated air dogs and off sets.

Carriage Drives: New hydraulic and electric feed works, although relatively expensive, claim increased output by decreasing sawyer fatigue and lowering down-time to frequent maintenance. The hydraulic carriage feed uses the power obtained from the husk shaft or separate motor to turn a hydraulic motor which in turn imparts power to the cable carriage drive. Oil hydraulics in this application has proved to be a superior "muscle" to steam, since oil under pressure is easily controlled and the fluid medium is in itself an excellent lubricant, reducing wear in all moving parts to a minimum. Exceptionally low maintenance costs are claimed for this feed. An extra advantage of hydraulic feeds is that power can be taken from the pump to run other hydraulic appliances such as log turners and the live deck. Several small circular mills are now on the market that are completely hydraulicaly controlled, practically from log deck to slab conveyor. One such mill used for relogging cut-over pine stands in the west claims an output up to 30,000 feet per day with a three-man crew.

Electric carriage drives, somewhat more expensive than hydraulic, necessarily require electric power. The principle of this drive is briefly the conversion of AC current to DC, thereby obtaining instant reversibility in the drive motor by reversing the direction of the current by means of a controller similar to that used by the old fashioned electric street cars. One great advantage claimed by this drive is that the energy produced in braking the carriage is fed back into the line resulting in overall low current consumption.

Edgers and Trimmers: Improvement in edgers and trimmers has also been evident, although possibly not quite as spectacular as in carriages and carriage drives. Today we have shadow-line lights synchronized with the movement of edger saws as well as electric-controlled saw shifts. These, however, are relatively expensive and whether they justify the high initial investment in a small mill is rather questionable.

Saws mounted directly on the motors of the trimmer along with the electric powered saw shifts are a distinct advantage over the old fashioned manually controlled line-shaft trimmer. A machine of this type developed and installed by the author in his mill has performed exceptionally well over a period of years. With this machine, the trim saw operator finds he can shift his saws much faster and therefore produce more accurately trimmed and better grade lumber.

Lumber Conveyors and Sticking Jigs: Lumber conveyors have improved only in that more of them are powered today as compared to the gravity or hand fed type. The packaged handling of lumber in a sticking jig or similar device is definitely a time and money saver, especially where a lift truck is employed for stacking in the yard or on kiln trucks. Such a jig permits fast and accurate sticker placement resulting not only in neat looking piles, but a reduction in lumber degrade due to faulty sticker placement. Some mills when shipping green lumber have also resorted to steel strapping for easier unit handling by lifts and straddle trucks.

Sash Gang Mills: The recent introduction of the small European-style sash gang mill to complement the production of the conventional carriage mill may show the way to lower sawing costs in the utilization of small or low grade logs. A large over-run due to less saw kerf and greater accuracy of cutting can make the sawing of small marginal logs profitable, especially in softwoods, where grade is not too important. Some box mills are already using this type of mill for producing low cost box lumber.

Conclusion

The justification of any monetary outlay in improving a mill set-up is only in the increased net revenue thus obtained. Naturally new machines which reduce manpower requirements for existing production rates or increase production without increasing manpower requirements can be considered a means toward this end. So can machines which increase the quality of the lumber without affecting production.

It becomes more and more obvious, therefore, that in today's changing economy new developments in sawmilling are rapidly becoming a necessity for the continued profitable operation of many of our mills in the Northeast.

Acknowledgment

The author wishes to acknowledge sawmill data supplied by the forestry departments of the states of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, and New York, and for the information on new equipment supplied by numerous mill manufacturers.

Discussion

Russell Dennison (Dennison Lumber Co.): I saw a double end trimmer with individual motors. What do you think of this?

Mr. Tolle: I might mention that I designed such a machine several years ago. This was inspected by F. C. Simmons and C. J. Telford at the Forest Products Laboratory and information on this was published. Some mills on the West Coast use this type machine and I believe that one Eastern manufacturer has it on the market. A flexible electric power line moves with the saw and is so arranged as to keep out of the way of the saws. The controls for moving the saws are so arranged

that the operator has time to figure out his setting. The saws operate on solenoid stops and saws move just to the stop. With such a rig, it is necessary to have a man who can be trained readily.

Nelson Nash, (Great Eastern Lbr. Co.): We hear a lot about the poor manufacture of lumber in the Northeast. I think you will find that Northeastern lumber manufacturers sell lumber in other sections of the country where they have these fine machines we hear about. The reason we here in the Northeast are not a paradise for machinery salesmen is not so much that we do not want to buy these machines as it is that some of the traditions in the Northeast, particularly in New York State, are such that we cannot afford to go out and buy too much due to constitutional difficulties with which I will not bore you. Under the State laws, the State Forests do not contribute to our timber supply. I have just one question—Who makes the shadow line?

Mr. Tolle: The Carter Corporation in Grand Rapids is one firm that makes it.

Anon.: Is there any explanation for the low percentage of band mills in this region?

Mr. Tolle: One reason is that the band mill requires considerably more capital investment than the circular mill, and many of our operators find it difficult to raise the required amount of capital. That is why we have so few of the other improvements such as sash gang saws. Also, there is a lot of gravel in our soils which can cause plenty of trouble when the logs are dirty. I know of one instance where dirty logs put a band saw man out of business. There is also the problem of saw maintenance which creates a big overhead. In our mill if we cannot produce at least 5,000 bd. ft. a day, we are below the profit margin. If we had a band mill, we would have to cut a lot more than that to break even.

J. Harry Rich (University of Mass., Amherst): Do you think the new feed works and carriages warrant the high capital outlay? Will you expand on the results in better manufacture and high grade yields from such improvements?

Mr. Tolle: I believe that these are improvements that are relatively high in cost. Our particular organization is definitely working for improved machinery, but it is also limited by finances. I think that many small operators can, with planning, work into a program of new equipment which will be very helpful. For instance, I know of an operator near here who produces only fair lumber. He is still using the same mill that he bought after the war for $400. He has never spent a nickel on his mill, but every year buys a new car which costs him over $4,000. He considers spending several hundred dollars to buy new set works which would improve his lumber grade as an unnecessary investment.

Q.: In handling logs and lumber with a fork lift we find that in the winter we have difficulty keeping the logs on the forks. Is there a device for holding the logs on?

Mr. Tolle: I do not know if I can answer your question because we have never run into this problem. Possibly wider spacing of forks would help.

Comment: Our fork lift is a conventional rig with rubber tires. It might be a good idea if we had something like that.

Mr. Tolle: Most of the fork lifts have a tilt back arrangement which throws the logs back so that it is difficult to see how they can be lost, unless the tractor goes over such rough terrain that it tips sideways.

Comment: Our fork lift is a tilt back arrangement but in the winter when the logs are icy and we are handling them one at a time, they slip off sideways.

Mr. Tolle: I think you need a new machine to solve your problems.

Forest Products Research[1]

H. E. DADSWELL[2]

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Discusses the role of applied and fundamental research and the best type of training for the fundamental research worker. The author believes that fundamental and applied research must proceed simultaneously for the most effective results. A combination of biological and physical sciences is considered the best type of training.

THE COMMON DENOMINATOR of this Society is forest products research. This paper considers two particular aspects: (1) What type of forest products research do we need? (2) What training is essential to produce an efficient forest products research worker?

I have been engaged in the research field for 30 years, and in forest products research for most of this period. Moreover, I have been in a box seat watching developments in this field in my own country from the inception of a forest products research program to the present day, when we have a forest products laboratory with a staff of 230 of which some 50 are university graduates. One cannot live through a development of this kind without getting some ideas. I also have had the opportunity of studying at and visiting numerous other forest products institutions in this and other countries. Therefore, using as a basis varied experiences over the past 30 years, I propose to present some of my ideas on these points.

What type of forest products research do we need? My immediate answer to this question is that applied or *ad hoc* research is *not* the real answer. By this type of research I mean that which involves little more than the application of existing knowledge to the solving of the many everyday problems encountered in industry or the home—particularly the home, for the householder is one of the most important users of forest products. The answer is a much more complicated one.

However, I don't mean to belittle the value of applied research. For a new organization or laboratory in industry or for one that is handicapped by lack of funds this approach can be most effective—for a time, but even-

[1] Presented at meeting of the Pacific Northwest Section, FPRS, Feb. 28, 1955, in Seattle, Wash.

[2] The author was Walker-Ames Professor of Forestry, College of Forestry, University of Washington, at the time the paper was presented. On leave from his position with the Commonwealth Scientific and Industrial Research Organization.

tually it becomes more and more difficult to pull the rabbits out of the hat. We passed through this stage during the first years of the existence of our forest products laboratory; we were able to be of considerable assistance to the timber industry by applying results of forest products research obtained at the U. S. Forest Products Laboratory, where most of our staff was trained. This proved a very effective way of getting on our feet, but only because results of forest products research had never previously been applied there.

Aid in Depression

Then the depression came but we managed to survive on one spectacular result of *ad hoc* research, namely, the reconditioning of timber that had collapsed during drying. Our lightweight eucalypt timbers were and still are notorious for the collapse that occurs, but as a result of reconditioning, which was in effect only a high humidity (or steaming) treatment at the end of a kiln run, they were able to compete with imported timbers and are now used for many of the purposes for which Douglas-fir is used in this country. The depression really helped in that substitutes had to be found for imported timbers and with our help using results of the knowledge gained in this country, the eucalypt timbers were used widely for the first time. However, even to this day we have not completed much fundamental research on the question of collapse and recovery.

Having weathered the depression in this manner, we found that although application of knowledge obtained elsewhere was of great assistance, we could not last forever on such a basis. So we set to work on the fundamentals of the anatomy, chemistry, physics, and mechanics of our own timbers. Thus it may be said that the period between the end of the depression and the beginning of World War II was one in which quite an effort was made to grapple with a number of fundamental problems pertaining to forest products research.

During this period we began our systematic studies of basic wood anatomy, of cell wall structure, of wood chemistry in relation to the pulping of certain Australian timbers, of methods of assessing hardwood pulp properties, of electrical moisture meters, and of high frequency drying and gluing (in the latter cases our work was interrupted by the war and results were never published). These investigations paid off handsomely during World War II when, with the increased technical developments, demands were made on us for all kinds of information pertaining to the utilization of Australian and New Guinea timbers. In many cases our pre-war fundamental studies gave us the answers we needed in selecting or rejecting timbers for certain purposes. Unfortunately, of course, it was impossible to carry out additional fundamental work during the war period.

At this stage there was another minor crisis in forest products research in Australia when it was claimed by some that all the research of any value in forest products had now been completed, and the organization developed during war years might well be broken up and members directed into other lines of work. This was purely a result of looking at the picture from the standpoint of applied research with no thought as to what might result from the many and varied fundamental investigations waiting to be tackled. Fortunately, those that held that forest products research was past its peak and on the down grade, did not win the day.

It should be pointed out that our Division of Forest Products is part of a large federal research organization and is not connected administratively with the Forest Services, either State or Federal. This has decided advantages in that the executive controlling our destinies consists mainly of scientific men of high reputation. And the executive in authority, just after the war, was convinced of the value of fundamental research.

At this stage, applied work was in the discard. We were not encouraged to accept problems from industry or individuals that required only the application of existing knowledge or the routine testing of numbers of samples. Here was a different state of affairs—one that appealed to the scientist interested only in the advance of knowledge for its own sake, but it brought as many problems as the other extreme where only applied research was tackled. There was great danger in the loss of contact with the trade, with industry, with the men actually handling timber in all its forms; such a loss of contact would lead to a lack of knowledge of real problems in the trade and would lead further to a tendency to move too far away from reality. Fortunately, we did not interpret the instructions too literally and kept a modicum of applied research going.

It is evident, therefore, that in forest products research there can be as great a danger in too much concentration on the fundamental side, as in too much attention to applied research without the backing of the fundamental.

There are unfortunately in the world today forest products organizations where lack of active fundamental research projects has caused stagnation. There are no new ideas, no new approaches to problems, and a general lack of incentive, yet today the industries based on the products of the forests are not standing still. They are developing and expanding and they need more and more basic information.

So, the type of forest products research that we need in our universities, our government research organizations, and in our industrial research laboratories is one that is active and progressive—a properly balanced mixture of the fundamental and applied. My own belief is that the ratio should be 60/40—60% fundamental to 40% applied; this ratio may and should be varied from time to time to meet conditions of the day but one has to be certain that the two go hand in hand.

Types Needed

What type of fundamental work is needed? There is that fundamental work usually undertaken by universities where the research worker follows any lead that presents itself and seems interesting. This type of work should rightly be carried out in universities. Then there is what might be termed the directed fundamental research usually carried out in government laboratories and industrial laboratories where there is some degree of control or channelling along certain desired lines. This too is fundamental work. The only real difference between it and that carried out in universities is that unprofitable lines or sidelines, even though interesting, are dropped in order to follow up those likely to be of most value eventually. We follow the directed fundamental work channel and hold various conferences to advise us what industry and the trade in general are interested in.

What makes me so certain of the value of fundamental work? In our own laboratory, the work centered on the structure of the wood fibre and on the structure and properties of reaction wood has paid handsome dividends. At least we are led to believe so by our Australian pulp and paper industry —the research representatives of which we meet every year around a table and discuss our results. They are emphatic that we continue along these lines, although solutions to their everyday problems may not be immediately forthcoming; they agree that there has been and will be ample evidence of results on which their own research men can capitalize. To summarize briefly, our work on fibre structure and

the relationship between structure and properties has led to the idea that it is possible to breed or produce a strain of trees from one species growing in Australia, namely *Pinus radiata,* with fibre and wood properties superior to those at present obtained. By detailed study of the properties, structure, and development of reaction wood, particularly the tension wood of hardwood, knowledge has been gained of the processes of lignification in the growing tree.

All this fundamental work of recent years in our own and other laboratories has only been accomplished by the cooperative efforts of scientists of a number of different disciplines. Thus in the section of Wood and Fibre Structure in the Australian laboratory, we have botanists, foresters, chemists, and physicists. Forest products research in the fundamental sphere has developed so rapidly in recent years that we find it necessary to keep up-to-date in the use of modern laboratory methods, and the standard compound microscope of the wood structure laboratory is now supported by such tools as the polarizing microscope, the electron microscope, the reflecting microscope, the flying spot microscope, and the x-ray diffraction apparatus—along with, of course, the more commonly known tools of the chemical laboratory.

What training is essential to produce an efficient forest products worker? It is manifestly impossible for anyone to be trained adequately in all the scientific fields I have mentioned. But I can assure you that, in my opinion, there can be a *best* training. You cannot take a graduate in any one discipline of science, no matter how highly trained in that discipline he is, and expect him to turn into a first-class research worker in forest products in a short time. We think that it takes such a man about two years to become of value.

I was taken from the safe haven of an instructorship in organic chemistry at the University of Sydney into forest products research at the U. S. Forest Products Laboratory, Madison, Wis. The two and a quarter years I spent there was a period of training deliberately arranged by our Australian scientific authorities. Others of our staff were trained the same way. Even this way of training fails with some, particularly chemists and physicists. Wood, and forest products in general, are not ideal materials to work with. No two pieces are ever the same. All too often the man trained only in the physical sciences loses sight completely of the fact that wood is a product of a living organism and represents the result of the many changes that have taken place in the life of that organism. The lack of exact methods of analysis, the tendency to frustration due to the variability of the material, and the difficulty of isolation of any pure chemical compound have all combined to thwart many first-class research workers and they have not remained in forest products.

It all goes back, I feel, to the undergraduate training in the university—at least in our country and in England—and I suppose in this country too—where there is too much specialization too early. We find that men graduating in the physical sciences have absolutely no appreciation of the biological sciences. Yet I venture to say without fear of contradiction that the great demand today is for the biochemist and the bio-physicist. Alternatively, you can get graduates in biological sciences, particularly in botany and zoology, who have had only the bare necessities of chemistry and physics. For all research people a broad basic training is essential. If I could rearrange schedules at various universities, I would see that in the freshman year every student in science would have some botany, zoology, geology, chemistry, and physics, even if the whole series of courses given in these sciences had to be changed and even if at graduation the individual was not as highly specialized as he tends to become today. Within each science, greater broadening is also desirable.

All the above has been directed at the training in science and there has been no reference to the man graduating in forest products from schools of foresry. In Australia, at least, such a man is of considerable value to industry and to a research organization. However, without further education, he does not have the type of training suited to the present-day needs of fundamental research in forest products. His training is best suited for applied research and for contact with industry.

What then, in my opinion, is the best training for the research worker in this field? The best type of training combines a biological and a physical science, for example, training in botany and chemistry. This combination we have found eminently suitable and training in botany and physics is equally suitable. These combinations are admirable for present day requirements in forest products research; the knowledge of botany making certain that the difficulties of dealing with products from living plant organisms are fully appreciated, and the knowledge of a physical science making certain that present day methods of attack on biological problems can be handled efficiently and effectively. We have found from time to time that unfortunately the chemist or the physicist is completely astray in his approach to a problem because of lack of appreciation of the biological aspects. We have also found that the fundamental study of both the structure and the chemistry of the material—wood, or other products of the tree—is most essential for its best utilization.

Therefore, my two thoughts on forest products research are: (1) that fundamental and applied research must proceed simultaneously for the best and most effective results, and (2) that the best type of training for the fundamental research man in this field is one that combines biological and physical approaches.

Operational Research in the Wood Turning Industry[1]

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The importance of operational research on the plant level to the wood turning industry is discussed. Examples are given of how such research can lead to more efficient operations and procedures. The value of other levels of research to the wood turning industry is also pointed out.

THE MAIN OBJECTIVE of this paper is to introduce the wood turning industry to the Forest Products Research Society. It will describe what wood turning is and tell the role of research in the wood turning industry.

What Is Wood Turning?

Wood turning is one of the smallest divisions of the great forest products industry. Its nature can best be gleaned by a glimpse at the products it manufactures. Most of its products are between 3/8 inch and 3 inches in diameter and between 3/8 inch and 6 inches long. Some specialty items, such as lawn mower handles, may be considerably longer.

It includes such items as wooden balls, beads, wheels and other toy parts, handles for kitchen utensils, cutlery handles, croquet balls, golf tees, and tops for whiskey bottles. Wood turning also includes dowels and dowel glue pins used for holding furniture parts together. This industry produces very few end items ready for the market; rather, it is primarily a supply industry furnishing component parts. As such, severe tolerance limitations are imposed upon it.

Most of the wood turning plants are in New England, with a focal point in western Maine. This may be traced to the historic fact that Maine has been the center of the nation's white birch population, and for turning there is no species that is its equal.

So much for wood turning's scope, products and location. What is wood turning really like. Perhaps its real nature can best be defined by revealing the industry's attitude on a wide variety of matters.

Research is the foundation of the wood turning industry. It is inseparable from good management, good production, acceptable techniques, and a superior product. Why do we place research on a pedestal? Research is by definition the revision of generally accepted conclusions based on newly discovered facts. Obviously, without getting new facts and without probing to discover whether traditionally accepted axioms are true, no competitive business can long endure. That is why research is the key to enlightened management and operations and why it is the single most significant entity in wood turning. The entire profit and loss statement is determined by having facts, not traditionally accepted axioms, and by taking decisive action on these facts.

This industry, of course, recognizes various levels of research. It recognizes formal research projects, speculative and theoretical research, and the tremendous value of shared research as exemplified by FPRS. But basically major emphasis is placed on operational research—research at the plant level.

What can operational research do for wood turning or wood processing? Many plants belong to research societies, subscribe to research journals, and spend large sums in formal research projects—yet have one fatal void in their program. They fail to collect simple, everyday facts that are available to them in their own plants—facts that could alter their entire modus operandi and turn loss into profit.

The wood turning industry believes that just one fact, a single venture in operational research, consistently followed and acted upon can lead us to revise not one but many conclusions regarding the health of our operations. One simple set of facts may lead us to revise our entire thinking regarding efficiency of machining, operations, and procedures.

Consider the simple fact of material usage. Naturally, wood turning plants must and do have a method of estimating the number of board feet of lumber that will go into an end product. Estimated material usage is, of course, a prerequisite to quoting prices intelligently. Many plants are content to stop with a method of estimating. However, every wood processing plant should follow this estimate with an operational research project and develop a method of recording after production whether usage was above or below estimate for each item produced.

The common reaction to a plea for accurate usage information is: "Why try to pinpoint usage so fine? I know we haven't been losing money. My estimating method is certainly accurate enough." This is a pseudo fact. Enlightened management and operations depend on actual facts, not pseudo facts.

Spotlights Profitable Production

To demonstrate this, assume that a plant is producing just two products—large handles and small handles—both from 1-inch squares. It is estimated that 40 board feet of lumber will be required to produce 1,000 small handles and 60 board feet will be required to produce 1,000 large handles. At the end of the month, checking general usage of 1-inch squares, it is found that usage amounted to the exact number of board feet estimated. Wonderful? It is if you are willing to accept pseudo conclusions and come up with pseudo profits. However, operational research might have revealed that 25 board feet—not 40—was used to produce 1,000 small handles, and 75 board feet—not 60—was used to produce 1,000 large handles. It would be disastrous to add machines to a plant to produce large handles and at the same time to discontinue production of small handles. Yet by knowing the facts of actual usage on the small handles, prices might be decreased, additional orders secured, and profits boosted.

What else can the simple fact of material usage reveal? It can also spell out sub-standard operations. All too

[1] Presented at meeting of Northeast Section, FPRS, April 28–29, 1955, in Glens Falls, N. Y.

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frequently uniformity of performance is mistaken for successful performance. Accurate usage data can prevent that pitfall.

For example, until a few years ago, all squares for our turnings were dried in hot boxes. Even though we were in a competitive position, we suspected our drying methods were responsible for much so-called "normal" spoilage —in-process loss due to fuzzing, splitting, porous-ended handles, and the like. With accurate lumber usage figures as a starting point, we engaged the services of a modern kiln, sent our yard foreman to kiln-drying school, and it at once became evident that the yield from well kiln-dried lumber was 10 to 12 per cent greater than from lumber dried by the hot-box method. This led to complete modern kiln conversion. Thus, by the persistent use of one fact, one venture in operational research, we revised drying methods at an annual saving of not less than $25,000.

This same method of accurate use records also told us that a newly designed machine in its pilot stage could not only speed our production rate, but could also reduce spoilage at the machine by as much as 7 per cent. Again, research at the operational plant level paid off. These are some of the benefits from one fact consistently acted upon.

Suggested Research

Here are some further operational research projects which the wood turning industry deems essential before sane, operational conclusions can be drawn and policies established.

Machine Speeds: The wood turning industry believes that speed of production of every machine and every process in its plants must be known and that actual production per unit in relation to its operating speeds must be pinpointed.

Spoilage Factors: This industry believes that not only must we know how much material is used to produce a given number of units, but also the number of pieces that are spoiled between initial stages of operation and final stages. Having pinpointed the number of pieces spoiled, then we must know the major reasons for scrapping.

Labor Costs: The exact cost of labor per unit of production must be known. This does not mean the total amount of labor that was paid for at any given machine or any given department. Two-thirds of that labor may not have been directly associated with the actual turning process, but may have been dissipated on such indirect charges as machine set-up time. However, it is imperative to know what it actually cost to turn 1,000 golf tees, for example, as opposed to what it cost for supplemental labor, which may or may not have contributed directly to the turning of the golf tees.

Machine Tolerance: This industry further believes that it must know the normal range of tolerance of which every machine is capable, and further know whether the machines are consistently run within those tolerances.

It follows that the wood turning industry is interested in those broad fields of speculative and theoretical research where pure theory is formulated without regard to its consequence. No industry could or would wish to act as a clearing house for those vast reserves of speculative ideas. Thus we look to our schools of forestry and to forest products laboratories as a source of great ideas which have been formalized into formulae and put into usable industrial form. For example, little did the theoretical mathematician dabbling in theories of chance dream that some day his conclusions would be systemized and passed on to industry in the form of statistical quality control, nor that simple average and range charts, watched by men who little understand their background, could one day save the wood turning industry thousands of dollars.

The above are some of the ventures in operational research which the wood turning industry considers imperative to keep its operating system flexible and current. Just as with an operational research venture in material usage, each of these projects can uncover countless facts that will cause revision of previous conclusions and vast alterations of operations.

Current Concepts Based on Research

The following describes some beliefs of the wood turning industry based on past operational research projects.

Kiln Drying: Earlier remarks about kiln drying may have implied that the wood turning industry is of necessity wedded to kiln drying. However, turning can generally be accomplished much more rapidly and with greater ease from wet lumber than from kiln-dried. Kiln drying has little place in wood turning unless considerations of close dimensional stability, fine finishes, or low inventories enter the picture.

For example, visualize a ¼-inch hole in a handle held to a tolerance of minus .000 plus .003 inch, in air-dried lumber. It must be a classic assumption of the uninitiated that a ¼-inch hole in such a handle parallel to the axis of the wood's growth grows larger with drying and smaller with increase in moisture content. This is not true, however. The hole becomes smaller in both diameters as the wood decreases in moisture content. It also becomes distorted due to the differences in radial and tangential shrinkage.

The classic example of fast turning is a bailwood handle which is turned green at rates from 80 to 140 per minute. These bailwood handles are dried after turning, and quite naturally dry out of round. Most turnings, however, are faced with the realities of dimensional stability, and here it is of utmost importance that modern kiln-drying methods be used. Without the best of drying, spoilage increases and yield decreases just as rapidly.

Heat Treating: The wood turning industry believes that hand-forge treating of woodworking tools should be abolished in favor of modern heat treating methods. By this one expedient, better steel can be used and knife life increased by as much as 400 per cent. Non-productive machine time due to "touching up" knives can be reduced by as much as 50 per cent. This technique has the further effect of reducing spoilage and increasing quality levels.

Unit Stacking: The square is the standard piece of lumber used in the wood turning industry. Progressive firms believe that plants which purchase a major portion of their squares from an outside source or saw their own squares at a distance from their turning operations should consider means of having suppliers palletize lumber in unit packages. These may be shipped ready for unloading to dry storage or kilns so that no hand touches the lumber between source of supply and the first in-process operation. A saving of at least four handlings can be effected, and a monetary savings of up to $25 per 1,000 board feet realized.

Machine Design and Quality: Progressive wood turning firms believe that if a competitive item is being made, it must be made faster and more efficiently than by its closest competition. That is basic in any manufacturing process. To judge the effectiveness of any new design, progressive firms believe that new machines must improve the process by virtue of increased speeds, closer tolerances, and less down time to the extent that savings will pay for the machine in no more than four years.

Such firms also believe that all machines must be engineered with an accuracy of dimension considerably in excess of quality demands imposed upon them. If a firm is required to consistently drill 70 inches per minute on turning machines and hold a tolerance of minus .000 and plus .005 inch, the machine should be so engineered to assure at least a minus .000

and a plus .003 inch consistently. This leaves some margin for human error and machine wear. It is also axiomatic that today's machines must be designed to process a wide variety of the more refractory species of wood, such as maple, walnut, and gum; such exotic species as rosewood; and even the high density modern wood-plastic combination, compreg.

Conclusions

It is apparent that the wood turning industry considers operational research —at plant level—the single most poignant venture that can be undertaken in the name of research. It should also be noted that we are interested in the application of the best in those broad fields of research which culminate in such useful techniques as statistical quality control.

The wood turning industry is equally interested in the level of research exemplified by FPRS meetings. That is the level of research whereby we revise conclusions based on facts that may be new to us but have been common knowledge to others in the wider fields of forest products for some time. It is obvious that new ideas are so ubiquitous in the great forest products industry that wood turning firms couldn't possibly keep abreast of the times if it were not for a central place into which experience of the entire industry could be fed and processed into easily digested packets of diverse and useful application. The wood turning industry must participate in joint enterprises of this nature or eventually wither on the vine.

The aim of research in all forest products industries is not the pure love of expressing techniques and procedures, it is an interest in eliminating economic waste and in saving dollars and producing better products. An analysis of the last 50 papers presented before this Society show that 13 involved the quality of raw material, in-process material, and finished goods; 12 were practical expositions on manufacturing technique, layout, and operating procedure; 11 were straightforward expositions on machinery and its effective operation; 8 dealt with waste utilization; 4 were concerned with specialized products; and 2 discussed new and specialized techniques. Thus it is apparent that our joint aim, whether at the formal, shared, technical, or operational research level, is greater efficiency, less waste, and superior profits.

Consumer's Point of View on Fruit and Vegetable Shipping Containers[1]

C. B. MOORE

Executive Vice-President, Western Growers Association, Los Angeles, Calif.

Recent developments in packaging fruits and vegetables are discussed. Problems encountered in using various containers are pointed out. Research is needed regarding the best type of crate for different uses, its carrying ability, and transportation practices throughout the country.

THE VEGETABLE SHIPPING INDUSTRY of California and Arizona is comprised of the largest group, as far as tonnage is concerned, of any perishable shippers in the United States. This industry has always been users of wood, preferably sawn materials.

Some 20 years ago, the wirebound box was introduced into the fruit and vegetable industry of the country. About six or seven years ago, a group in the San Francisco area decided to build large vacuum tubes in which they could precool vegetable commodities. They centered their entire activity in an experimental way in the Salinas, California, area, where a tube was built which would hold approximately one-half carload of packed lettuce crates and where the temperature could be reduced rapidly to the desired 33 or 34 degrees, an operation which took about 20 to 25 minutes.

At the start of these experimental shipments, all the containers used were the standard lettuce containers then in the container tariffs of the railroads, and listed under the state standards of the California standardization laws. All were made of sawn materials.

Due to some heavy periods of production, when markets were badly glutted with lettuce, certain shippers conceived the idea of field packing this lettuce in fibreboard cartons approximately half the size of the standard wooden crate. These cartons were then transported to the vacuum cooling tube, cooled, loaded, and shipped under standard refrigeration to eastern territories, arriving in excellent condition. This evolution—or revolution —practically changed the entire lettuce picture in all producing districts of California and Arizona. At the present time, more than 85% of all lettuce moving from California and Arizona is moving in paper cartons vacuum cooled.

Consumer-Size Packages

The carrot industry since its inception has packed carrots in bunches, with the green tops on which were the badge of freshness to the purchasing consumer. About 10 years ago, some of the chain store groups decided to sell carrots by the pound and started to purchase carrots with the tops clipped off and packed in gunny sacks or wirebound containers according to the desire of the purchaser.

The large chain store groups throughout the country have strived for 100% self service fruit and vegetable divisions in their retail stores and have been anxious to get these commodities shipped to them in a consumer package. With the production of polyethelene film, several shippers started packing carrots in consumer-size polyethelene bags, and that has spread rapidly through the whole industry. These consumer-size bags are packed in a mother container, the majority of which are wirebound crates at the present time.

There have been many experimental shipments in the same manner in fibreboard. This procedure on both carrots and lettuce, the two heaviest tonnage commodities that we ship, has made a great change in packing house methods. Most of our shipping territories

[1] Presented at Session V, Packaging, FPRS Ninth National Meeting, June 21–24, 1955, in Seattle, Wash.

The Author: Chester B. Moore was associated with the railroad industry and was a bank official before joining the Western Growers Protective Assoc., now known as the Western Growers Assoc., in 1928. He served as Secretary before promotion to his present position.

have shipper-owned ice plants and, with the disuse of the wooden containers where both package ice and body ice could be used, many of these ice plants are practically out of business.

The railroads performed the bunker icing of these cars in many of the districts and have contracts of long years' standing with private ice companies. Therefore the shipper-owned ice companies are of little value in many districts.

Recent Experiments

Shippers are experimenting with cauliflower trimmed so that there are only a few jacket leaves surrounding the curd and these curds are wrapped in a consumer-type package—either cellophane, pliofilm, polyethelene, or parchment paper. In most of these shipments, the standard broccoli crate is used instead of the standard flat cauliflower crate which has been in vogue many years. This cauliflower is packed two tiers to the crate.

Our greatest problem today with wooden containers seems to be with the cantaloupe crate. The breakage records which the railroads give us show a tremendous amount of recooperage necessary. We are presently involved with a case before the Interstate Commerce Commission, wherein the railroads have attempted to force us to an on-end load of these standard cantaloupe crates, similar to the load now used by the citrus industry where wooden boxes are concerned. We are protesting this before the Commission, because we are convinced that the melons are being bruised due to their weight in the crate during the 7 to 10 days' transportation across the country.

Experiments are being made with a new larger jumbo cantaloupe crate, termed at the present time as the Azhderian crate, which is considerably larger than the standard jumbo crate. If the shippers do not attempt to overload this crate, it may be the answer to some cantaloupe shipping problems.

This summer, several hundred cars of cantaloupes packed in a telescope type of fibreboard container will be shipped, as well as some experimental shipments in the flap-type fibreboard container. Out of this eventually may come a complete revolution in the type of containers used for melons.

There is one matter in connection with the use of fibreboard that is disturbing many shippers. During certain seasons of the year, lettuce is being shipped which is inspected at shipping point through the Federal-State Inspection Service and a certificate issued. Upon arrival at eastern markets, the receiver reports heavy decay and asks for a reinspection by Federal inspectors. In hundreds of these cases, the notation is placed at the delivered end that the commodity—lettuce in this case—was not in suitable shipping condition at time of shipment. The P.A.C.A. officials and the Department of Agriculture are holding with the delivered inspection and the shipment is being rejected. The shipper then has to market this to the best of his ability and always at a considerable loss.

A few leading shippers are commencing to doubt the wisdom of shipping lettuce in fibreboard containers, vacuum cooled, under standard refrigeration. They believe that, at least at certain times of the year, the majority of this lettuce should move in wooden containers that can hold ice, as well as being capable of top icing the load as has been the practice in the past.

This is a matter that is going to take a considerable amount of research to determine the facts. Then the industry will decide whether it will continue to handle commodities in fibreboard cartons or whether at certain seasons of the year the shipper will go back to sawn containers, shipping through their packing houses, with crate ice and top ice.

There are from 65,000 to 70,000 carloads annually of lettuce moving out of California and Arizona and an additional carlot equivalent of 20,000 to 30,000 carloads moving by truck from the producing districts. So this is a matter of extreme importance to the producers of containers, whether they be manufacturers of sawn wooden containers or fibreboard.

The celery movement from California and Arizona is about equally divided between the sawn wooden containers known as the sturdee crate and the wirebound container of approximately the same dimensions.

Species Used

For many years, practically the entire sawn crate production was made from ponderosa pine. However, in recent years the stumpage situation has changed materially and the producers had to use more white fir or Douglas-fir. We have had trouble, especially with posts and rails used in the construction of sawn wooden containers, when we are furnished with cross grain hard material other than ponderosa pine. However, we understand that probably never again will there be sufficient ponderosa pine available to make all wooden containers.

Many manufacturers in western territory have been interested in the development of a paper-laminated veneer crate to compete with the fibreboard container, and a considerable amount of experimental shipping has been done in this so-called TKV-type crate. It may be the answer to some problems if the crate can be produced cheaply enough to compete with the fibreboard container, which would give us the advantage of using this TKV crate with both container ice and body ice on top of the load. It is doubtful if we will ever go back to the large standard crates that were used for many years. Retailers throughout the country are opposed to the handling of these heavy containers. Much of the work is done by women who can handle, both physically and under the state laws, the smaller containers which are now being used in fibreboard.

There is room for a tremendous amount of research, both as to the type of crate, its carrying ability, and the transportation practices now in effect in this country. We are in a period of evolution and only time, experience, and practice will give the proper answer. This is demonstrated in the revisions made in the standardization laws in both California and Arizona for lettuce and carrots. A few years ago there were only four containers for lettuce and two for carrots. Now there are more than ten different size lettuce containers and approximately that many more for carrots. State standards, of course, apply to size only and these standard crates could be made of any of the three types now used—sawn material, wirebound, or fibreboard.

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Around the World in Forest Products Research and Development

Distribution of Shear Stress in a Glued Specimen of Isotropic or Anistropic Material

E. Niskanen. State Institute for Technical Research, Helsinki, Finland. 1955.

A number of calculations have been performed with Fourier series and Fourier integrals, with the objective of studying the kind of distribution of shear stress in a double shear specimen in accordance with Fig. 1, and in a single shear specimen in accordance with Fig. 2, in the joint surface proper (FG and EH in Fig. 1, EF in Fig. 2), if the joined specimen displays 1) isotropic, or 2) anisotropic behaviour. Birch timber has been chosen to represent the second alternative.

As a result of these calculations, it has been established that in isotropic material the maximum of the shear stress tends to form in the vicinity of the upper and lower surfaces of the specimen, whereas in the corresponding anisotropic case the maximum tends to develop near the center of the glue joint. With the increase of the ratio $H : a$ (see Fig. 1), stress concentrations tend to come into existence even in the anisotropic case symmetrically above and below the center of the joint; the result obtained at the value $H : a = 3 : 2$ is indicative of this behaviour. However, no calculations have been performed for higher values of $H : a$.

As a general observation, in the anisotropic material, under conditions set out in detail in the calculations, the distribution of shear stress in the joint is more uniform than in an isotropic

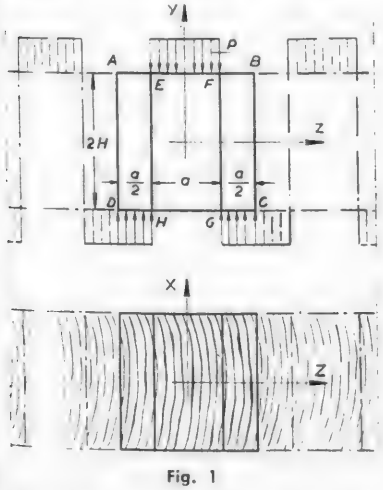


Fig. 1

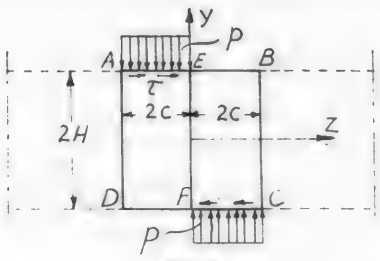


Fig. 2

material. This is particularly true at large values of the ratio $H : a$. The specimen under consideration has been assumed to be of infinite length in the direction perpendicular to the load, and normal stress parallel to the horizontal z axis is therefore produced in the outer surfaces (AD and BC in Fig. 1 and 2) of a finite specimen to which the results are applied. The complete elimination of these stresses is difficult in the double shear specimen, but fortunately they appear to have relatively small influence upon the shear stress prevailing in the joint surface proper. The glue layer in the joint has been assumed to be thin enough so that its elastic or plastic properties need not be taken into account, and thus the results will apply even in a case where there is no glue joint.

Scanning World-Wide Forest Publications

Drvna Industrija. Vol. VI, No. 9-10, 1955. Output of Raw-Material in Parquet Flooring Manufacture, Franjo Pavletic.

The situation with raw-material for parquet flooring manufacture in P. R. Croatia is analyzed. The author states that the production of parquet flooring in near future with foreseen fellings and present output will be about 774.400 sq. m. of parquet yearly, i. e. only 82.34 per cent of the capacity of the existing plants. The present output, which is in average 32 sq. m. of parquet boards per 1 cu. m. of raw parquetry strips, must be raised by improving all production steps, from logging and sawing to the production of parquet flooring itself.

The present practice in logging is to put all logs with a diameter smaller than 25 cms in pitprops. As the logs with 20–24 cms dia are too big for pitprops, they should be used as sawing logs for the production of parquetry strips. Grading in sawmills should be made less rigidly, because much of the third grade lumber nowdays becomes degraded to fuel wood or to wood for the extraction of tannins. All this lumber could be converted into parquetry strips. The purchase of up-to-date sawing machinery with thinner blades also improves the lumber output, which in oak should be raised 48 per cent. In this way the production of parquetry strips would also be raised.

The old Yugoslav standard for parquet boards prescribed tongue heights of 5.5 mm, whereas according to the new standards, the factory in Slavonski Brod produces parquet boards with 3.3 mm tongue heights. This new method represents a considerable saving: The output with the old method was 31.66 sq. m. of parquet boards per 1 cu. m. of parquetry strips, whereas the output of parquet boards with 3.3 tongue heights is 32.64 sq. m. from the same amount of parquetry strips.

Journal of the Japan Wood Research Society. V. 2, No. 1, 1956. Shrinkage of Wood in Kiln Drying. Yasushi Suzuki.

The effect of drying condition on apparent shrinkage after drying of 28 mm beech board (*Fagus crenata* BL.) is studied. The drying curves for test specimens dried under various conditions are shown. As the moisture gradient in thickness direction of board is nearly proportional to the drying rate in a series test of the same temperature, the magnitude of drying stress caused by moisture gradient can be relatively indicated using the value of drying rate. Therefore, the set after drying (difference of shrinkage between the test specimen and set-free thin section) are plotted as a function of drying rate (average in the stage from initial to 40% moisture content).

Positive set means over-shrinkage of heat-dried specimen. The quantities of compression set in width direction, i. e. tangential direction in these tests, decrease with the severity of drying, and that in thickness direction, on the contrary, increase with it. In most of the runs of drying test, compression set due to collapse which generally advances at higher moisture content is not found. The effects of air-seasoning before heat-drying and of the temperature upon the set built up in both directions of dried board are shown.

Abstracts From Current World Literature

Laminating

Gray, J. M. The supply and grading of Douglas Fir laminating stock. *B. C. Lumberm.* 39 (4), 1955 (72 . . . 75).

Describes the difficulties of launching the original specification, and revising it to produce the present Canadian Standards Association specification 0122 for the selection and grading of laminating timber. The most equitable combination of grades to cover the normal distribution in production is suggested, and a plea is entered for the general acceptance of the Standard and for more research on timbers (other than Douglas Fir) e.g. Hemlock, suitable for laminating. [For. Abs. V. 16, No. 4]

W. T. Curry. Laminated beams from two species of timber. Forest Products Research Special Report No. 10, 1955.

Laminated beams are made by gluing layers of wood together with their grain directions parallel. They have advantages over solid timber beams in that large beams can be made from small stock, they can be shaped and they are stronger. Beams can also be constructed from two species of timber, relatively thin laminations of a strong dense species of wood being glued to a core of a weaker, lighter species; this type of construction is both more economical and stronger in relation to its weight.

Experiments with two-species beams gave satisfactory results and provided a basis for the design of such beams. Clear material only was used for the investigation: defective material would obviously reduce the strength of a beam.

When two-species beams are subjected to concentrated loads, there is a danger of the core material being crushed. [F. D. C. Tech. Bul. V. 5, No. 28]

Barking

Salminen, Jaakko. Barking of small wood with the Kuori–Peto barking machine. *Paperi ja Puu* 37, no. 10: 484–9 (Oct., 1955). [In Finnish; English summary]

A report on the Kuori–Peto barking machine (I) developed in Finland is given. (I) is intended for the complete clean barking of small hard- or softwood, at least one meter in length and 5–11 cm. in diameter. The barking parts are four detachable blades which cut by slashing and are mounted on blade holders on four rotating rings. The blades are capable of removing even fairly long branch stubs from the surface. The barking waste in the form of short shavings is expelled from the machine by means of a centrifugal blower. For transportation (I) is supplied with solid rubber tires; in this form the machine weighs about 980 kg., exclusive of the power engine. The power may be supplied either by a separate electric or combustion motor or by a tractor via belt or axle transmission. Experiments with (I) were made in the spring of 1955; the crew consisted of three men. When green non-frozen softwood logs 2 m. in length and with an average unbarked diameter of 8 cm. were fed, the output of the machine was about 5 unbarked piled cu. m/working-site hour. With frozen or sufficiently seasoned logs the speed would have been considerably higher. About 89% of the barked timber was completely freed of black and bast bark; the residual 11% contained some black and bast-bark spots. The loss of wood varied from 3.6 to 8.2% solid measure. The cost of barking wood completely clean by hand is two to three times greater than with (I). Further savings in (I) barking can be achieved by improving the layout of the storage site and better organization of the work. [Bul. Pap. Chem. V. 26, No. 4]

Waste Utilization

Narayanamurti, D., and Singh, Harcharan. Studies on building boards. Part IX. Utilization of wood waste, tree barks and other lignocellulosic materials as a source of plastics and building boards. *Composite Wood* 2, no. 3: 53–62 (May, 1955); *cf. B.I.P.C.* 25:701.

Continuing the work of Narayanamurti and J. Singh (*cf.* B.I.P.C. 25:519) on the thermal hydrolysis of lignocellulosic materials, three different barks (sal, kanyu, and kosh barks), agricultural and forest wastes (areca-nut husks, pine needles, etc.), and white cedar and bamboo sawdust were given the thermal treatment in a stainless-steel revolving autoclave in laboratory experiments. Analytical data of the raw materials and after their hydrolysis at 160 and 170° C. are included. Molded products and boards were formed from the hydrolyzed powders; the detailed results are presented in tables and graphs. [Bul. Pap. Chem. V. 26, No. 4]

Fire Protection

Scheldt, Robert A. Dry chemical fire equipment in the paper industry. *Tappi* 38, no. 8: 175–7A (Aug., 1955).

The author shows how the use of water in fire fighting with ensuing water damage to expensive equipment can be greatly reduced when accompanied with initial dry chemical fire control and fire knockdown to such an extent that only an amount of water necessary to quench the remaining embers must be used. The application of dry chemical in woodyard and woodroom, chip bins, acid plant, wet room and screen room, beater room, and in the paper-machine area (particularly if the machine extends through the floor) is discussed. [Bul. Pap. Chem. V. 26, No. 1]

Utilization

Work, Herman, Pulp and lumber industries join hands. *Paper Maker* [U. S.] 24, no. 2: 1–9 (Sept., 1955).

The discovery by men of both the lumber and the pulp industries that they could work together led to the pioneer step in 1927 when a new company started to make kraft pulp from wood chips cut from bark-free slabs, edgings, and nonmerchantable leftovers from the Long–Bell Lumber Co. sawmills. Problems in the utilization of these pieces, conservation of the procedure in raw-material supply, recent growth of new kraft mills, and benefits to lumberman, pulpmakers, and the public are discussed. Thus at the present time, two giant industries dependent on the same source of raw material are working energetically toward a goal of complete utilization. Both the industries and their customers stand to benefit permanently from all progress in this direction; the benefits are in terms of more goods and more utility, at prices that should continue to encourage the expansion of markets for forest products. [Bul. Pap. Chem. V. 26, No. 3]

Economics

Kauffman, Erle. The Southland revisited. Parts I–III. *Am. Forests* 61, no. 8: 33–40; no. 9: 11–16; no. 10: 14–19, 84, 86, 88, 90–2, 94, 112 (Aug.-Oct., 1955).

The economic revival of the South brought about by the emergence of its forest industries under sustained management, was begun about 30 years ago with an educational program which formed the people of the South into an informed and interested public giving support to a program where industry, government, and the people worked together for the betterment of all. Pulpwood production in the 12 southern states has risen from 7,200,900 cords in 1941 to 16,300,000 cords in 1954. The question of future wood supply and demand, the pattern of land ownership and the growing problems of management and protection on the fastest growing industrial region and forestry's greatest frontier—the South—are examined and the opinions of many leaders in the industry cited. [Bul. Pap. Chem. V. 26, No. 4]

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiber board and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

FORESTRY ABSTRACTS, published quarterly by Commonwealth Agricultural Bureaux, Farnham Royal, Slough, England, subscription price $8.40 per year. The abstracts are prepared by the Commonwealth Forestry Bureau, Oxford, England, and include a Forest Products and Utilization section. This section contains over 1,500 titles and abstracts per year from literature in some 30 languages, covers all aspects of forest utilization.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

Preview of FPRS Section Meeting Papers

Automatic Control Techniques in Wood Processing

Lloyd E. Slater, Managing Editor, Control Engineering, New York, N. Y. FPRS Northeast Section Meeting, Nov. 4-5, 1954, New York City.

The original concept of automation —integrated and mechanized materials handling—is one which can quickly be adopted by the wood plant manager and will lead to immediate benefits. However, the basic engineering art of automation in its broadest sense is the art of automatic control engineering. The real future opportunities for better, more profitable wood processing will come through the basic application of this art.

Three factors underly all production operations and these same factors—hooked together by engineering—underly automatic control. These are the factors of cause, effect, and feedback. In any operation in the wood plant, this basic triumvirate is found. Wherever a man is doing something, he is exerting manual feedback. If some operation is done to a product on the move that requires judgment and there is no man, you have automatically controlled feedback—or simply automatic control.

Proven Worth

Automatic control, in the continuous dynamic sense, has already proven its worth in kiln drying. Practically all kilns are now equipped with remote bulb indicating or recording control instruments and pneumatically operated valves which throttle heating medium and exhaust atmosphere. This basic combination of sensor (temperature bulb), error measuring device and controller (instrument), and effector (control valve), could well be a prototype for many similar systems in tomorrow's wood plant. Man's function of "see, judge, and do" along a highly mechanized line is essentially a quality control one. When instruments are devised to simulate this quality gaging, an automatic feedback system could be set up to handle the job.

In many operations, a man reads a continuous gaging instrument and then applies manual feedback to the machine or operation. An example is the use of ammeters on the three-drum sander. Instead of manual re-set of drum pressure from this reading, why not design automatic feedback into the system to hydraulically position the drum?

Ultrasound has proven an excellent means to continuously detect internal flaws in material. It is possible to visualize this type of probe measuring wood on its way to a delicate machining operation, with automatic feedback rejecting improper material or resetting the machine according to product structure.

Wood density is a basic factor in strength and workability. Perhaps some of the new, continuous radiation-type density gages developed for metal and fluid products could be applied to wood on the move. This would allow, perhaps, automatic control of a working machine directly in accordance with each particular piece's ability to be machined. Such a system might increase cutting pressure or speed, or actually shift a new engaging edge into the machine to suit the raw wood.

Another technique with great possibilities for the wood plant is control by automatic counters, which can register several thousand counts or pulses per second. These pulses can originate from a variety of operations on the production line. Hence the line speed, wood dimension, number of pieces stacked, etc., can be picked up by some electrical pulsing device and the rate in question read directly on the counter. A predetermined count can be set as a control for these various factors and the counter can actuate any desired sort of control to integrate or adjust line operations.

True automation in the wood plant can come through the endorsement of far-sighted management who will allocate the needed technical man hours of basic study and experimentation to further this art in the plant.

Contemporary Trends in Furniture Design

J. W. Crist, Assistant Professor of Art, U. of Illinois, Champaign, Ill. FPRS Midwest Section Meeting, April 11–12, 1955, Champaign, Ill.

Traditional or period furniture is an imitation of some style of the distant past and is always made of wood. Often its construction is expensive since it is better suited to the hand-built techniques of the past than to industrial processes.

A change has taken place in furniture design over the past few years. Broadly speaking, the change is toward a kind of design that is better suited to the way we live and to our industrial methods of manufacture.

For the past six or eight years, the dominant influence on furniture styles has been Scandinavian and Italian design. In place of the rather simple and austere design of the immediate post-war years in this country, this foreign influence has produced a decided trend toward more flowing and sculptural forms in which the structure and joints have been forced almost to their limit to support the stresses involved.

In Italy and Scandinavia where expert wood craftsmen are numerous, time and care can be given to accomplish this safely and well. In industrialized America, creating these structures by machine is not so easy. The impact of this fluid style is sharp, however, and the furniture industry in this country will prefer the materials which will give the desired results simply and directly.

Wood is still the dominant material of the furniture industry. With careful planning and alertness to changing needs, it will continue to hold this position.

Meeting Challenges

It is imperative that the importance of appearance as a sales factor be recognized. In areas where appearance counts most, in furniture and on surfaces, wood faces a real challenge from other materials. Wood has many appearance factors in its favor—its warmth, pleasant grain, traditional use —but some effort must be made to learn more about such factors and to exploit them.

Ways might be found to introduce more color into wood or wood finishes. All processed woods such as hardboard and particle boards need to have color "built in".

Much can be done to glamorize imperfections in wood, to turn disadvantages into profits, as has been done with knotty pine. Many other low-grade woods probably have similar qualities which can be exploited to advantage.

Mutual Advantage

New and improved methods of joining wood members must be found. Such a system might well be an actual metal joint attached to or mounted in the wood member. Metals and plastics are here to stay. A sensible course would be to utilize these materials in conjunction with wood whenever it is prudent to do so. Rather than trying to meet the challenges of these materials head on, wood utilizers should take the lead in joining them to wood for the mutual advantage of all.

Finally, a specialist in appearance should be consulted on all these matters. His specific knowledge and ability can be of infinite value in helping wood to meet today's demands.

FPRS News-Digest, Continued

NEW PRODUCTS—LITERATURE

Adhesive Bulletin

A new bulletin covering woodworking adhesives durability tests on specimens made in 1939 has been issued by the Borden Company Chemical Division, 350 Madison Ave., New York 17.

The reported results are a continuation of tests on plywood aged 10 to 16 years under various exposure conditions at the firm's laboratories at Bainbridge, N. Y. Specimens are 3-ply, made of 1/16-inch birch veneers glued under recommended conditions of spread, temperature, press cycle, etc. The panels were not treated with protective coatings.

The bulletin also gives comparison of various types of adhesives on various veneer species under continuous unprotected outdoor exposure for five to ten years. Copies of "Durability of Woodworking Adhesives" are available from the above address.

Materials Handling Described

Articles on the latest developments in lumber handling, how to save when ordering hardboard products, and unitizing construction forms appear in the Spring 1956 issue of "The Signode Seal", available from Signode Steel Strapping Co., 2630 North Western Ave., Chicago 47, Ill. Other articles cover air power tools and other packaging developments.

Hand Truck

A hand-operated stair-climbing truck has been developed by Precision Equipment Co., 3714 N. Milwaukee Ave., Chicago 41. Two rocker-arms act like an extra pair of wheels, keeping the truck on a constant line for friction-free travel and eliminating the dragging of loads over curbs and up and down stairways.

The unit, called E.-Z Climber, is built with a 1-inch tubular steel frame and has a reinforced base plate beam. It has semi-pneumatic 10-inch by 2.75-inch steel disc wheels, and a load capacity of 600 lbs. The truck is 46 inches high by 18¾ inches wide.

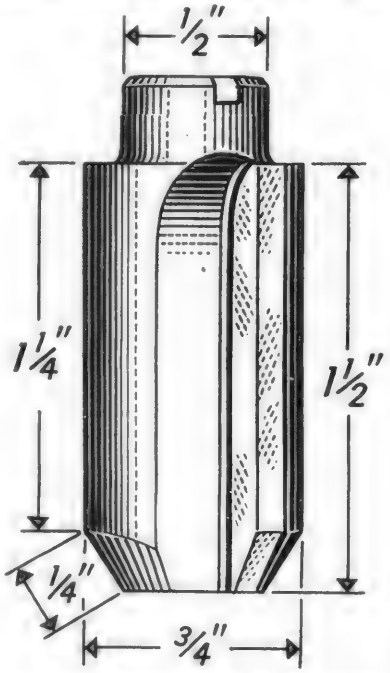
Strainer Steam Trap

A larger, integral strainer steam trap is being manufactured by Armstrong Machine Works, Three Rivers, Mich. The integral strainer protects the trap from harmful sediment, scale, or other foreign particles that may be present in steam lines. This new model, no. 883, is used for pressures up to 250 psig. Capacity is 3500 to 4400 lbs./hr. of condensate. Side inlet, side outlet, screwed pipe connections are furnished either ¾ inch or 1 inch.

The integral mechanism of the trap is stainless steel with lapped valve and seat of hardened chrome steel. The materials, workmanship and design of the internal mechanism are the same as in the Armstrong high pressure forged steel traps used for service up to 900 lbs., 900° F. The integral strainer feature reportedly saves on installation labor, requires less fittings, and costs less than a trap and separate strainer.

Carbide Router Bit

A new ½-inch diameter model multi-purpose router bit designed especially for high pressure plastic laminate work is being manufactured by Oakland Carbide Engineering Co. The new



tool, which previously was available only in the standard ¼-inch shank size, is reported equally efficient for flush-trimming, under-cutting for self-edging, and bevel trimming operations.

Illustrated literature is available from Price & Rutzebeck, 22150 Meekland Ave., Hayward, Calif.

Finished Wall Paneling

A new technique in pre-finishing interior wood wall paneling is being used by Hi-Grane Board Co., P. O. Box 7013, Fort Worth 11, Texas. The paneling is available in yellow pine and fir plywood.

A process of burnishing and brushing leaves a "grained" effect on the wood, and tone-on-tone colors make possible a 3-dimensional finish. Marketed under the trade names of "Hi-Grane" and "Pli-Grane," both products are said to have a smooth finish and are economical finished panel ng. Hi-Grane yellow pine is available in six colors plus natural grain, while Pli-Grane is available in 12 colors lus natural.

Torque Converters

A torque converter for every horsepower range from 40 to 1,000 is now offered by Twin Disc Clutch Co., Racine, Wis. Four distinct sizes are offered, with a total of 29 capacities, through internal blading variations. The newest series, No. 13,800, is planned around a basic unit, with easy-to-add components which produce ten specific models. This permits interchange of components to provide a model adapted to a wide variety of applications.

Reported advantages of the entire line include up to 6:1 torque multiplication at stall; engines work in their maximum efficiency range at all times; power is automatically matched to load demands; smooth, even pick-up of heavy loads is provided without clutch slippage; overloads, shock loads and vibrations are cushioned out, through fluid connection; and an infinite number of ratios are available. A variety of power input, output combinations are offered to match any engine hook-up.

Paint Marketing Film

A film in 35 mm sound slides "Color in Action" demonstrates the Martin-Senour Paint Company's customized color center program for paint distributors and dealers. It illustrates the dealer program for maintaining a complete paint stock with minimum inventory, yet assuring a wide latitude of color selection for the customers. Large inventories are eliminated through an obsolescence-proof mixing system which combines tube toners

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The film received top award for the best sales film in 35 mm sound slides at the fourth annual National Visual Presentation Association's competition.

Furniture Fasteners

A method of fastening furniture legs which may reduce assembly time, materials needed, product weight, and production costs has been developed by Heli-Coil Corp., Danbury, Conn. In the assembly of wooden furniture frames, short wooden legs are attached to the front corners with hanger bolts. Formerly, two steel plates were secured to the bottom of the frame by wood screws, a process requiring six steps.

Now the wooden legs are screwed into metal thread inserts in the wood. The only steps required are drilling the hole, tapping, and installing the insert. The threaded hole is then ready to receive the leg.

NEW PUBLICATIONS

The Air Seasoning and Preservative Treatment of Crossties from Eight Oregon Conifers. R. D. Graham, Oregon Forest Products Laboratory, Corvallis, Ore.

Sheathing Board from Ponderosa Pine Mill Residues. W. H. Cooke. Report No. L-4, Oregon Forest Products Laboratory, Corvallis, Ore.

Lateral Tests on Full-Scale Lumber-Sheathed Roof Diaphragms of Various Length-Width Ratios. J. W. Johnson. Report No. T-9, Oregon Forest Products Laboratory, Corvallis, Ore.

Vertical Treatment of Posts Superior to Horizontal Treatment. C. S. Walters. Forestry Note No. 68, U. of Illinois Agricultural Experiment Station, Urbana, Ill. Study was made to determine effect of soaking position on results of cold-soaking shortleaf pine posts in an oil solution of pentachlorophenol.

Chemical and Biochemical Effluent Purification. E. Farber and D. V. Robertson. Wood Research, March 1956, Timber Engineering Co., Washington 6, D. C. Reprint from Tappi. Discusses four approaches to cleansing industrial waste waters.

Wood Frame House Construction. Agriculture Handbook No. 73, U. S. Forest Service. Government Printing Office, Washington 25, D. C. Presents principles for woodframe house construction and suggestions for selecting suitable materials. Deals essentially with established methods. 236 pages. 65 cents.

Commercial Methods of Forming Balsa Cores for Thick Curved Reinforced Plastic Structures. Richard Mark, Balsa-Ecuador Lumber Corp., 550—5th Ave., New York 36, N. Y. Presented at 11th annual technical and management conference, Reinforced Plastics Division, Society of Plastics Industry, Atlantic City, N. J., Feb. 8, 1956. Describes methods employed when balsa cores are used in curved and/or irregular sections, including flat-grain cold-bending, flat-grain bending under the action of steam or hot water, end-grain bending and draping for both large and small radii of curvature lamination, crushing, nest cutting and die punching.

Sawdust Mulch Aids Tree Survival. Forestry Note No. 69, U. of Illinois Agricultural Experiment Station, Urbana, Ill. Series of tests were initiated to determine effects of a sawdust mulch on Christmas tree plantation.

The Utilization of Waste Wood in the Northeast. Equipment Handbook Release 256, American Pulpwood Assoc., 220 E. 42 St., New York 17, N. Y. Describes cooperative arrangement between two companies who have pioneered in utilization of sawmill wastes. Chips from one firm's five sawmills are sold to pulp and paper company, augmenting latter's supply from own sawmills.

Traction Chains for Farm-Type Rubber-Tired Tractors. Equipment Handbook Release 259, American Pulpwood Assoc., 220 E. 42 St., New York 17, N. Y.

From Forest to Front Page. Roscoe C. Martin. U. of Alabama Press.

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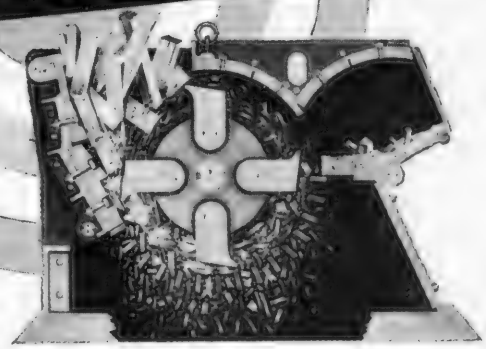

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FPRS News-Digest, Continued

$1.25. Describes process by which newsprint producer locates a major plant (Bowaters Southern Paper Corp., Calhoun, Tenn.) Case study was financed by grant from Resources for the Future, Inc., to Inter-University Case Program for studies of administrative aspects of natural resource problems.

Roof Decks and Built-Up Roofing. Federal Construction Council Technical Reprint No. 1. $1. Building Research Institute, 2101 Constitution Ave., Washington 25, D. C.

The following publications are available without charge from the U. S. Forest Products Laboratory, Madison, Wis.

Comparison of Wood Preservatives in Mississippi Post Study (1956 Progress Report). J. O. Blew, Jr., and J. W. Kulp. Report 1757. Describes the condition of posts installed in a long-term exposure test and compares the effectiveness of the wood preservatives used to treat the posts.

Grain Separation and Related Defects in Douglas fir door stock. E. M. Davis. Reprint from the Wood-Worker.

Compressive Buckling Design Curves for Sandwich Panels with Isotropic Facings and Orthotropic Cores. C. B. Norris. Report 1854.

New Veneer-Lumber Flooring Developed for Concrete Slabs. D. A. Zischke. Reprint from the Southern Lumberman.

Paper-Overlaid Planks Provide Smooth, Durable Stadium Seats. B. G. Heebink. Reprint from the Southern Lumberman.

Moisture Content of Wood in Use. E. C. Peck. Report 1655, Revised. Presents data and recommendations that will enable the user to select the correct moisture content for wood used under various conditions.

Effect of Long-Term Loading on Glass-Fiber-Reinforced Plastic Laminates. Interim Report No. 1. K. H. Boller. Report 2039.

Tensile Properties of Glass-Fabric Laminates with Laminations Oriented in Any Way. E. C. O. Erickson and C. B. Norris. Report 1853.

Supplement to Stresses Induced in a Sandwich Panel By Load Applied at an Insert. W. G. Youngquist and E. W. Kuenzi. Report 1845–A. Presents results of tests using panels having honeycomb-type cores.

Supplement to Directional Properties of Glass-Fabric-Base Plastic Laminate Panels of Sizes That Do Not Buckle. A. D. Freas and F. Werren. Report 1803–B.

Deflection and Stresses in a Uniformly Loaded, Simply Supported, Rectangular Sandwich Plate. M. E. Raville. Report 1847.

Thickness Variation of Lumber Cut by Circular Mills. C. J. Telford. Reprint from Southern Lumberman.

New Drop Tests for Fibreboard Boxes. K. Q. Kellicutt and E. F. Landt. Reprint from Fibre Containers and Paperboard Mills.

Plans for Research on Forest Genetics at the Forest Products Laboratory. H. L. Mitchell. Reprint from Tappi.

Hardwood-Distillation Industry. E. Beglinger. Report 738, Revised.

Need for Uniformity of Temperature in a Forced-Air-Circulation Ventilated Compartment Dry Kiln. E. F. Rasmussen. Report 1669, Revised. Describes some of the ill effects of nonuniform drying conditions and discusses some of the major causes of nonuniform temperatures.

The U. S. Forest Products Laboratory. F. J. Champion. Report 1698, Revised. Describes the history, philosophy, purpose, organization and accomplishments of the U. S. Forest Products Laboratory.

News and Views of this Kiln Drying Business. G. J. Warfield. Report 1769–20 tells how to design a sticker rack and guide so that lumber can be unloaded from a boxcar and piled directly onto kiln trucks, ready for cross-piled kilns. Report 1769–21 by P. Padgett describes a system of roller conveyors that make it easy for lumber handlers to renew their supply of green stock while they shift the stickered piles to holding docks to await the fork lift truck. Report 1769–22 contains the plans for and describes the use of portable "lumber lids" for the protection of packages of dry lumber when sheds are not available.

Statistical Evaluation of the Effect of Age on Specific Gravity in Loblolly Pine. D. O. Yandle. Report 2049. Presents an analysis of data to determine the statistical significance of observed trends of increasing specific gravity from the pith outward.

Breeding for High-Quality Wood. H. L. Mitchell. Report 2050. Discusses the relationship between wood quality and such properties as the density of the wood, proportion of summerwood to springwood in the annual rings, number of rings per inch, length and thickness of wood fibers, and orientation of the fibrils.

Some Books and Pamphlets on Finishing of Wood and Furniture. Technical Note No. 195. Contains titles of 35 publications.

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No. E 229a—Eastern veneer and plywood manufacturer seeks experienced man for plant superintendent. (June)

No. E 230—Southern state forest service seeks men holding M.F. or Ph.D. degrees with specialization in wood technology or wood utilization for combination investigative research and educational work. (June)

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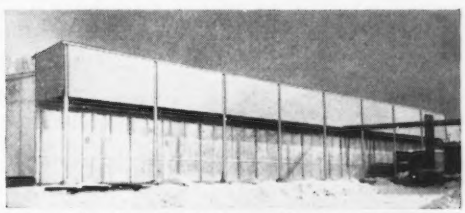

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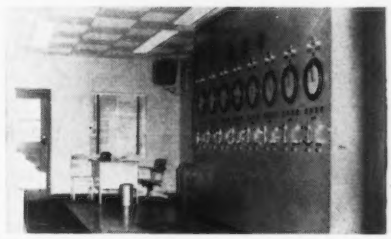

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INDEX TO ADVERTISERS

American Cyanamid Co. ---------- 2nd Cover
American-Marietta Co. ---------- 7-A
Black Brothers Co. ---------- 6-A
Borden Company ---------- 16-A
Buss Machine Works ---------- 5-A
Chapman Chemical Co. ---------- 3-A
Delmhorst Instrument Co. ---------- 36-A
Fjellman American, Inc. ---------- 4th Cover
Greenlee Bros. & Co. ---------- 2-A
Laucks Laboratories, Inc. ---------- 35-A
Masonite Corp. ---------- 1[illegible]-A
Mattison Machine Works ---------- 3rd Cover
Monsanto Chemical Co. ---------- [illegible]-A
Morton Salt Co. ---------- 1[illegible]-A
Oliver Machinery Co. ---------- 36-A
Perkins Glue Co. ---------- 1[illegible]-A
W. H. Rambo ---------- 32-A
Reichhold Chemicals, Inc. ---------- 8-A
Standard Dry Kiln Co. ---------- 35-A
Williams Patent Crusher & Pulverizer Co. ---------- 33-A
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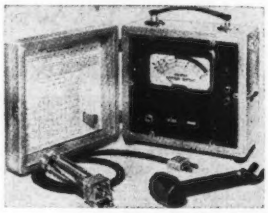

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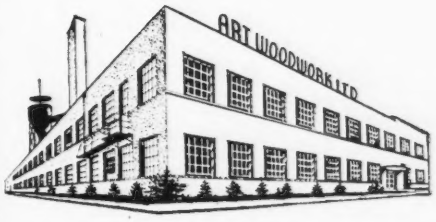
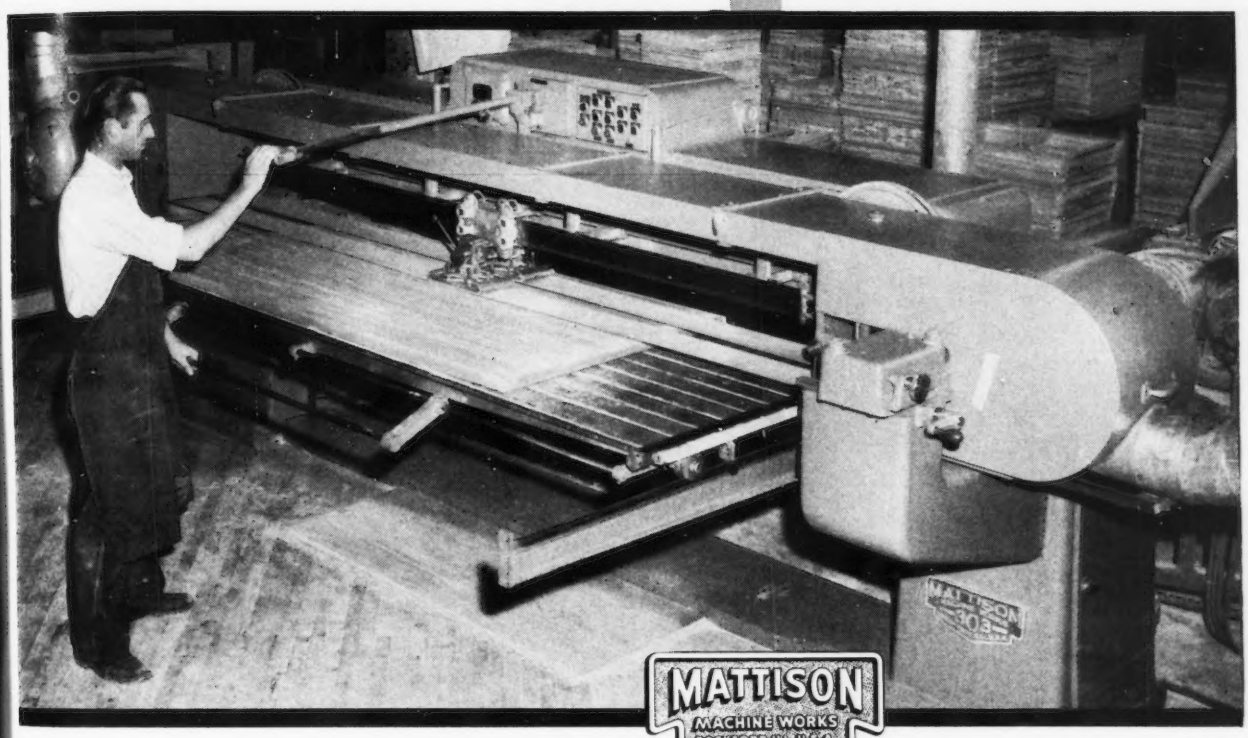
quality for Art Woodwork Ltd.





MATTISON
MACHINE WORKS
ROCKFORD ILL. U.S.A.

Sharply improved quality, increased production, and reduced operator effort were achieved when Art Woodwork Limited, Montreal, installed a Mattison 303 Double Belt Automatic Stroke Sander. Three hand stroke sanders were replaced by the new machine, with quality improvement that made substantial savings in hand sanding in the finishing department. Operators like the Mattison because centralized controls allow sensitive adjustment of sanding pressure for maximum output of perfectly finished work with minimum effort. Mattison developed the 303 for finish sanding of large, flat surfaces such as tops, panels, doors, and similar products. It is a machine capable of turning out *perfect work on a production basis*.

Return coupon below for catalog which describes all the features of the Mattison 303 Automatic Stroke Sander.

Mattison Woodworking Division
545 Blackhawk Park Avenue, Rockford, Illinois

Gentlemen: Please send bulletin on the Model 303 Stroke Sander.

Name_____

Company_____

Address_____

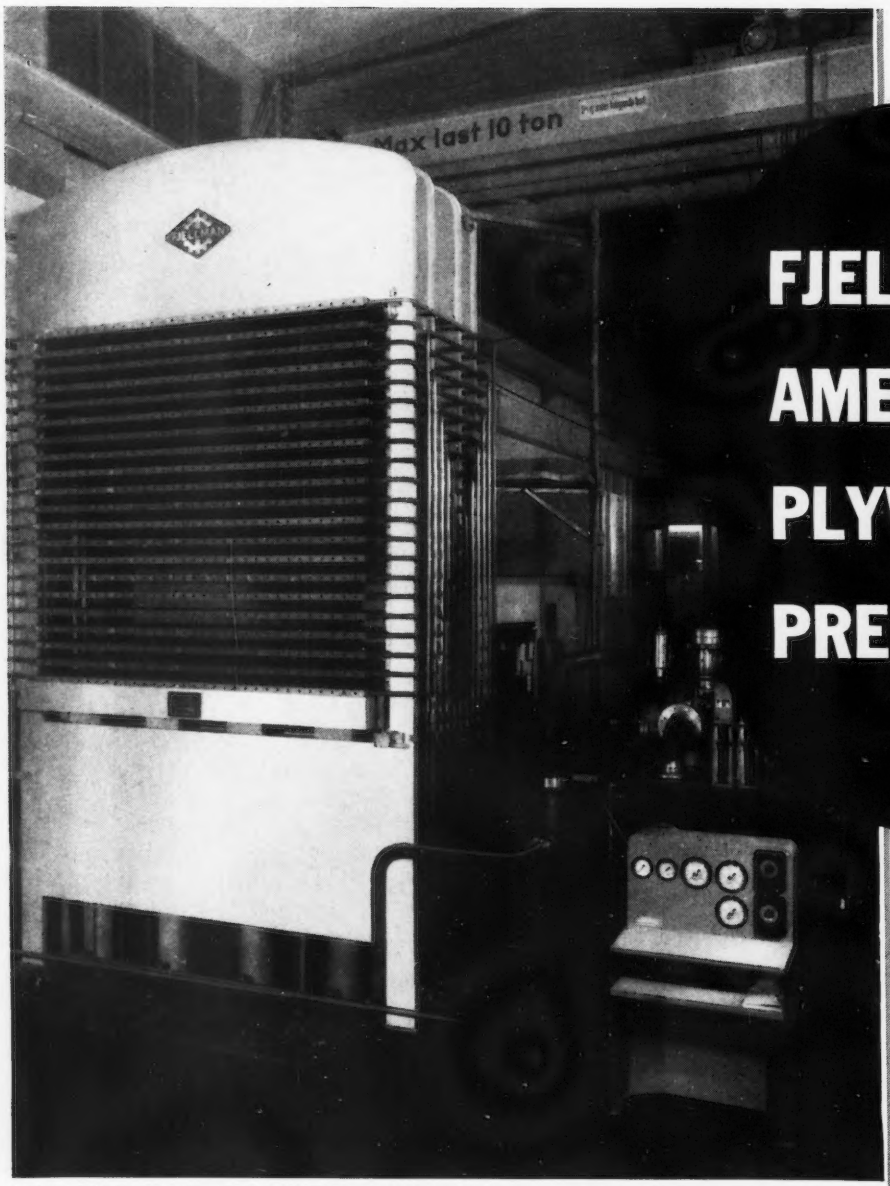
City_____ State_____

MONEY SAVING FEATURES

- Hydraulic system is simple but positive for stabilized stroke of counter-balanced aluminum sanding shoe under varying conditions.
- Operator has sensitive control of sanding pressure for maximum output, perfect finish, and minimum effort.
- Double belt machine reduces handling—coarse belt removes tape and glue, fine belt gives polish-finished surface.
- Centralized control panel includes single handle to regulate stroke length and sanding pressure, pushbutton motor controls, and shoe speed dial.
- Belt tension and alignment are adjusted easily with belts enclosed at top and ends for dust control and safety.
- Massive base and column construction assure maximum rigidity of the machine for permanent accuracy.

MATTISON
WOODWORKING MACHINERY

In The Finest Plants Throughout The World



FJELLMAN AMERICAN PLYWOOD PRESSES

Platen area 54" x 106"; 200 PSI over the entire platen area; total pressure, 660 tons.

Fjellman American enjoys close association with fine quality plywood production throughout the world. An impressive list of installations in leading plywood producing plants is available on request.

Reasons for Fjellman American's predominance in the industry lie in the all-Swedish steel construction of its presses eliminating dead weight in castings, light floor loading, easy installation, accuracy and long lasting dependability. Fjellman American's quick closing automatic presses give you the guaranteed constant pressure and uniform heat necessary to produce the finest plywood in the world.

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Manufacturers of a complete line of "hot" and "cold" presses for the furniture, plywood, and plastic industry.

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